H. W. Cronin M.D.

THE
ARTIFICIAL FEEDING
OF
INFANTS

THE ARTIFICIAL FEEDING OF INFANTS

INCLUDING A CRITICAL REVIEW OF THE RECENT LITERATURE OF THE SUBJECT

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PREFACE.

THE aim of this work is to place before the medical profession a thorough and reliable account of the principles and methods of artificial feeding in vogue at the present day. Much valuable material (not contained in the average text-book) has been collected, representing the results of extended scientific investigations. The substance of this work has been gleaned from the periodical literature, monographs, and text-books of the past eight years (1894-1901), so that this treatise may justly claim to be an authoritative statement of the views of the leading pediatrists and scientists of Europe and America on the subject of Artificial Feeding at the present day. Grateful acknowledgment is made of our indebtedness to the authors cited for their readily granted permission to quote from their works; especially we thank Professor A. B. Marfan, of Paris, Professor Monti, of Vienna, Dr. Cautley, of London, and Mr. H. Droop Richmond, chemist of the Aylesbury Dairy Company, whose names find frequent mention throughout the following pages.

It is inevitable in a treatise of this character that many repetitions should occur and that many conflicting statements should be made. Since the purpose of the work is to give a clear, impartial statement of the views of each author, detailed criticisms of their methods of feeding are avoided; but it has been the authors' aim to incorporate in the concluding chapters (XII., XIII., and XIV.) the guiding principles which

form the groundwork of all methods of feeding. An attempt has been made on this basis to construct a theory of infant feeding which shall be sufficiently broad in its scope to meet the widely varying needs of different infants, the cardinal principle being kept in mind that each case is a unit, and that we must carefully adjust the diet to the requirements of the individual infant if we wish to be successful.

The management of lactation (and wet-nursing) has not been considered, since it does not directly concern the purpose of this book.

Professor Henry Leffmann kindly consented to review the statements relating to the chemistry of milk and milk products, and Dr. David L. Edsall the chapter on Metabolism.

In conclusion, we desire to thank Dr. Harvey Shoemaker for much kind advice, Mr. Walter R. Cuthbert for his practical assistance, and our publishers for their courtesy and aid in the preparation of the work.

CONTENTS.

THE ARTIFICIAL FEEDING OF INFANTS.

CHAPTER I.

HISTORICAL.

A CURSORY survey of earlier publications treating of the artificial feeding of infants shows that the necessity of dilution to adapt cow's milk to the infant's powers of digestion was recognized as far back as the middle of the eighteenth century. In a treatise entitled "On the Raising of Healthy Infants," published by J. P. Frank in 1749, we read that Von Swieten, Loseke, and Cosner were the first to recommend diluted cow's milk for infant feeding; they advised to dilute from two to five times with water.[7] Frank advocated dilution with either plain water, barley-, wheat-, or oatmeal-water.[7]

The use of ass's milk and of animal broths seems to have found early recognition. JOHN ARMSTRONG, in "An Account of the Diseases most incident to Children," London, 1783, recommends that the nursing child should take, in addition to the breast, pap or panada made from bread-crumbs boiled in water and sweetened with sugar. If the child be artificially fed from the start, it should have "cow's milk mixed with its victuals as often as possible and now and then a little of it alone to drink. Ass's milk will be still better." If the milk disagrees, animal broths should be given. To assist teething and promote the secretion of the salivary glands, a crust of

bread dipped in water or milk should be given to the child to suck.

The next advance in methods of feeding among English writers is to be found in JOHN CLARKE'S "Commentaries on the Diseases of Children," London, 1815. This author was one of the first to advocate the employment of cream diluted with starchy decoctions; he also seems to have used whey as a beverage. To quote his own words: "Ass's milk is the best substitute for that of the mother—cow's milk is too rich and contains too much oil and cheesy matter. The latter is, moreover, formed by the gastric juice in the stomach into a firm curd, which is not digestible by the stomach of an infant. Diluting it with water does not entirely prevent this; therefore, when ass's milk cannot be procured, it is best to mix cow's milk previously skimmed with two-thirds or three-fourths of its measure of gruel made from pearl-barley, grits, or arrowroot. When so mixed it does not become hard in the stomach, . . . but forms a thick fluid. As a child advances in age the proportions of milk may be gradually increased. Where this food does not agree with the child, weak mutton, chicken, or beef broth, clear and free from fat, mixed with an equal measure of the mucilaginous or farinaceous decoctions above mentioned, may be tried. With some children, when no form in which cow's milk can be given will agree, the stomach will digest farinaceous decoctions mixed with cream. Solid animal food should not be given until the child has all the canine teeth, and then in small quantities and only once a day. Water either plain or with toasted bread infused into it, and rennet whey, are the best beverages for children. As soon as a child has got any of the teeth called incisors, solid farinaceous matter boiled in water, beaten through a sieve and mixed with a small quantity of milk, may be employed, and then for the first time the child should be fed by hand. When the molars or grinding teeth have protruded through the gums, the child should live upon farinaceous matter, mixed with milk or weak

broth, but the bread need not be beaten through a sieve, because the child has now an apparatus for grinding it."

The directions given by DEWEES for the preparation, handling, and administration of an infant's food are very similar to those in vogue at the present day. Dewees recognized the value of the application of heat to prevent decomposition of the milk, but advised against the use of prolonged heat at a temperature at or above boiling. We quote from the fourth edition of his work on Children's Diseases, Philadelphia, 1832:

"Milk should be diluted one-third with water and loaf sugar added to make the proportions resemble mother's milk.

"I. The milk should be pure, not skimmed or watered, and used as soon as possible after milking.

"II. When practicable, use milk from the same cow, to avoid variations.

"III. Mix sugar and water just before giving, to avoid fermentation.

"IV. Only the quantity should be prepared that will be used.

"V. Milk should be heated by adding hot water or by a sand-bath, not on a range.

"VI. Milk should be kept in the coolest possible place.

"VII. It should be rejected if acid. Too much must not be given at once.

"In cool weather, after the fifth month, barley-, rice-, or gum-arabic-water may be added to the diet if desired, also a small amount of arrowroot, or a small amount of some animal juice may be given in conjunction. After the child has its molars, the diet should consist principally of milk, to which grated cracker, well-baked stale bread, rice flour, or arrowroot may be added; occasionally, animal broths may be used, preferably beef, mutton, or chicken. After the eye- and stomach-teeth have erupted, small amounts of roasted meats may be added once a day. Stale bread and butter—the latter must be of good quality—are permissible at this age. Butter is not

only innocent but highly useful; the use of potatoes is not recommended, except in small quantities and only after the ninth month; they should be well mashed with hot milk, butter, and salt.

"I. Never put a second supply of milk upon the remains of a former, unless a very short interval has elapsed and they are of the same making.

"II. So soon as a child has taken as much as it chooses, or as much as may be judged proper for it, let the bottle be emptied of any food remaining and immediately cleansed by hot water.

"III. When well cleansed by the hot water, let it be thrown into and kept in a basin of cold water in which there is a little soda dissolved.

"IV. Before using let it be rinsed with clear cold water.

"V. Let the extremity from which the child is to suck be covered with a heifer's teat in preference to anything else.

"VI. Let not the teat be of too large a size, nor one that will permit too rapid a flow of the food, especially for a very young infant.

"Cow's milk contains more cheesy matter, and is on this account of more difficult assimilation; hence it is frequently thrown up in the form of a hard curd. Only so much milk must be taken into the stomach as the infant can assimilate and digest in due time; the latter may be fixed at three to four hours.

"Upon no occasion, when the child is in health, will the milk require boiling, for this takes from the milk some of its best qualities. In hot weather, it is true, the tendency to decomposition is diminished by boiling the milk, but as all the advantages which result from this process can be procured without its being absolutely boiled, it should never be had recourse to.

"It is every way sufficient for the purpose of preservation that the milk be put closely covered over a hot fire and brought quickly to the boiling point; so soon as this is perceived, it

should be removed and cooled as speedily as possible. By this plan we prevent in great part the formation of that strong pellicle which is always observed on the top of boiled milk, and by which the milk is deprived of one of its most valuable parts.

"For a certain period after each meal rest is essential to digestion, as exercise is important at other times for the general promotion of health.

"The preposterous and highly injurious practice of 'jolting' should be absolutely prohibited.

"The bottle must not become the plaything of the child.

"The child should not receive its nourishment while lying; it should be raised.

"When the child ceases to extract milk from the bottle, and this be restored to the child, who again refuses to take it, let the child on no account be urged to swallow more than nature seems to demand. This also holds good when the child is at the breast."

CARL GERHARDT [59] in 1871 recommended dilutions of cow's milk for different ages to be prepared in the following manner: for the first eight days one part of milk to three parts of water, from that time up to three months one to two, from four to nine months equal parts of milk and water, and after the ninth month pure milk. After the sixth month meat broth can be used as a diluent.

JOHN FORSYTH MEIGS, of Philadelphia, a renowned pediatrist in his day, was the originator of a mixture of milk, cream, gelatin, and arrowroot-water (see his text-book, second edition, 1853) which gave very satisfactory results for the feeding both of sick and healthy infants. He advised for a child of good health under one month from three to four ounces of milk, one-half to one ounce of cream, and half a pint of arrowroot-water (containing one drachm of arrowroot). For older children the quantity of milk was to be increased to one-half or two-thirds of the total mixture, and the cream raised to two

ounces. During the seventies he advocated the use of a mixture of equal parts of milk, cream, lime-water, and arrowroot-water, sweetened with a little sugar. In this preparation the principles governing modification of milk for infant feeding are correctly outlined, and it is not too much to say that all the later advances in method start from this fountain-head. The elder Meigs recognized the importance of adding cream to make up the deficiency in fat of his mixture, and it was due to his incentive that the younger Meigs pursued the question further, with the result of determining the proportions of the proteids in mother's milk, thus placing the question of dilution on a scientific basis.

The subject of the percentage of proteids in mother's milk was a mooted one until recent years. Chemical researches had given varying results, the methods employed being generally inaccurate. During the fifties and sixties the tendency was to accept the figures of Vernois and Becquerel, who had found a casein percentage of 3.924. Regnault, Simon, and Clemm obtained similar results, but Henri and Chevalier had found an average of 1.52 per cent., l'Héritier 1.3 per cent., and Quevenne 1.05 per cent. The latter figures were not, however, generally considered reliable, since they were based on a small number of cases only ("Milk Analysis and Infant Feeding," Meigs). Brunner, as far back as 1873, had published the results of his analyses of human milk, which gave him an average of from 1.3 to 1.4 per cent. casein (Pflüger's *Archiv für Physiologie*, Bd. vii.). On empirical grounds Biedert had arrived at the conclusion that the proper proportion of cow's milk casein in an infant's food was one per cent., and had formulated his Cream Mixture accordingly. Biedert's article in *Virchow's Archiv* for 1874 advised the use of a mixture of cream diluted four times with water, to which milk-sugar was to be added. He concluded from numerous experiments on the coagulability and digestibility of human and cow's milk that they varied in two important points: "first, in the dif-

ferent amounts of casein contained; second, in the absolute chemical differences of the two sorts of casein." [160] Biedert's Cream Mixture contained one per cent. casein, 2.4 per cent. fat, and 3.6 per cent. sugar of milk.

The question of the percentage of casein in mother's milk was still unsettled in 1882, when Arthur V. Meigs announced the results of his investigations, which determined the amount of proteids to be one per cent. (approximately) and the sugar seven per cent. These figures were based on analyses of the milk of forty-three women, the samples being obtained at different times and under varying circumstances. Starting from the assumption that cow's milk must be diluted sufficiently to reduce the casein percentage to that of human milk, Meigs devised the following preparation, commonly known as "the Meigs Mixture," which, in his opinion, meets the requirements of infant feeding.

[173] "There must be obtained a quart of good fresh milk; not too rich and not poor, average milk is best; this is placed in a high pitcher or other vessel and is allowed to stand in a cool place for three hours. The upper half or pint is then poured off, care being taken not to shake the vessel, and this upper pint, of weak cream, is to be kept for the use of the infant. The other half of the quart, which is skimmed milk, may be sent to the kitchen. There must also be made a solution of milk-sugar of the proportion of eighteen drachms to the pint of water. It is best to weigh the sugar, or to have an apothecary prepare a number of packages each containing eighteen drachms of milk-sugar. A wide-mouthed pint bottle should be provided, into which may be put eighteen drachms of milk-sugar and one pint of water. By having a wide-mouthed pint bottle there is no need for any other measure, and the sugar in bulk is more easily put into such a bottle than into an ordinary one with a narrow neck. The sugar-water must be kept in a place that is not too hot, nor should it be kept in a refrigerator, as great cold precipitates the sugar

and heat causes it to ferment. In hot weather the sugar solution should be examined from time to time, and if it sours must be thrown out and prepared afresh. Having the milk and the sugar-water ready, only one other ingredient is required, lime-water.

"When the food is to be used there must be taken of the weak cream (the upper pint which was poured off and retained) three tablespoonfuls, of the lime-water two tablespoonfuls, and of the sugar-water three tablespoonfuls. These substances together are placed in a feeding-bottle and warmed to the degree which may be desirable; the food is then ready for use.

"An infant two days old should take only about half an ounce of nourishment at a feeding, and it will take this amount seven or eight times each day; if it sleeps naturally, it is not possible to feed every two hours, which would make twelve feedings per day. The proper quantity, therefore, for a two-days-old child is between three and four ounces.

"The daily amount required will gradually increase, until at the end of twenty-one days it will be found that the infant is taking about two and a half ounces at a time, and still about seven or eight feedings in each day, making a total of from seventeen to twenty ounces. When the sixth week has been reached, about four ounces will be taken at a time, making a total quantity of nearly thirty-two ounces. These estimates of the amount of food for infants during the first few weeks of life may possibly be a little too high, but they will not be found to vary much from what babies should have at that period of life. . . . Generally a baby should not be urged to take more than it wants, unless it is very indifferent to food and takes much less than the quantities above mentioned.

"After the first six weeks it will be found that there is a natural desire for an increased quantity of food, just as there was in the earlier period. The amount taken by a healthy infant will increase to six or eight ounces at each feeding,

but generally the number of daily feedings will grow less. A very young infant will require to be fed seven or eight times a day, but one of from four to six months will only take nourishment from five to seven times a day. The quantity taken will be found to vary between somewhat less than two pints and three pints. The food, therefore, is to be increased in amount, but continued always of the same strength until an infant is from six to nine months of age."

Meigs has never been an advocate of sterilization under ordinary circumstances. "It certainly must alter the milk to be cooked, and sterilization is cooking, whether the heat applied be of high or only of moderate degree. It seems better and more natural to see that the milk is pure and free from all contaminations, in the first place, than to purify by sterilization a milk which is supposed to be contaminated, and then use it to feed babies. The field of usefulness of the process of sterilization is probably to be found in cases where it is impossible to secure pure milk, but as to using it as a matter of general application it is not to be recommended."

During an experience of fourteen years Meigs has used this food with great success. He estimates its composition as follows:

	Per cent.
Water	87.639
Fat	4.765
Casein	1.115
Sugar	6.264
Salts	0.217
	100.000

CHAPTER II.

MOTHER'S MILK.

Since mother's milk is universally recognized as the standard which should be imitated in the artificial feeding of infants, it will be the object of this chapter to give a succinct account of its composition and characteristics. No attempt will be made to discuss the physiology or the management of lactation, since the purpose of this work is to discuss the principles governing the artificial feeding of infants.

Description.

Mother's milk is the secretion of the mammary gland, and consists of an emulsion of small fat-droplets in which salts, sugar, and proteids are held in solution. At the height of lactation it is bluish-white and semi-transparent, of sweetish taste, odorless, and has a specific gravity of from 1026 to 1036 (Monti).

According to Leeds,[166] the color of milk, which may be chalky-white, bluish-white, yellowish-white, or yellow, is no indication of its composition. A chalky looking specimen may be rich in fat and a yellow sample poor in that constituent. Mother's milk has rarely a sweet taste; more often it is saline and of a somewhat disagreeable animal odor. Its consistence is much thinner and more watery than cow's milk.

Specific Gravity.

Adriance	1030	average
Richmond	1030–1031	average
Holt	1029–1032	
Monti	1030–1034	

Variations.

Johannessen	1025–1036
Leeds	1026–1035.3
Adriance	1017–1036

An increase of the fat lowers the specific gravity, a decrease raises it. The proteids and other solids have a reverse effect, while the salts are too insignificant to affect it one way or the other. As the sugar varies so slightly, it may be considered that, for clinical purposes, the specific gravity is modified solely by the fat and the proteids (ADRIANCE[69]).

In Monti's experience, "breast-milk which has a specific gravity of 1030 to 1035 and at the same time a fat content of three to five per cent.,—that is, in which the height of the specific gravity corresponds with that of the fat percentage,—and in which only slight changes in these factors occur during nursing, may be considered a good one." Low fat averages (from one to two per cent.) and low specific gravity (1026 to 1029) are found associated usually in the milk of anæmic, poorly nourished women. In those cases in which the woman's milk shows a high specific gravity and a low or subnormal fat content, the infants do not thrive, and such a milk must be considered to possess less nutritive value. The only sure test, however, is the child's weight.

Estimation of the Proteids. (*Holt's Method.*)

"In estimating the proteids certain suppositions must and can be fairly accepted.

"I. Supposing the proteids to remain unaltered; if the percentage of fat be low, the specific gravity will be high; but if high, the specific gravity will be low.

"II. Supposing the fat to remain unaltered; if the percentage of the proteids be high, the specific gravity will be high; but if the percentage of the proteids be low, the specific gravity will be low. If, therefore, the fat and the specific gravity be

known, any considerable variation in the proteids may be estimated by the following data:

Data.		Conclusion.
Percentage of cream.	Specific gravity.	Amount of proteids.
High,—*e.g.*, from 8–10	High, 1033–1034	High percentage
Low,—*e.g.*, from 3–4	High, 1033–1034	Nearly normal
High	Low, 1027–1030	Normal
Low	Low, 1027–1030	Deficient"

Holt asserts that the conclusions drawn from this mode of examination are as exact as those obtained by the ordinary examinations of urine.

H. Droop Richmond considers that "Holt's method is based on a fallacy," and that the results obtained with it are, on the whole, unsatisfactory.

Reaction.—Authorities are practically agreed that the reaction of normal mother's milk is uniformly alkaline.

Colostrum.

Marfan.[105] Colostrum is secreted by the mammary gland towards the end of pregnancy. It is a grayish-yellow fluid, of serous consistence and slightly turbid, containing streaks of deep yellow. Its reaction is alkaline and its density from 1046 to 1065.

Microscopically, there are found: (*a*) fat-droplets, some like those of normal milk and others smaller, poorly formed, and often agglutinated, which denote the imperfection of the milk secretion; (*b*) leucocytes, some of which contain fatty detritus; (*c*) colostrum corpuscles, large spherical bodies, consisting of fatty detritus surrounded by a membranous envelope, and often showing amœboid movements.

The first day after birth the secretion of the mammary gland contains many colostrum corpuscles and fat-globules of unequal size. With the appearance of milk on the third day the

colostrum bodies become less numerous, but the secretion still has a yellowish color. On the sixth day there are many fat-globules which are less unequal in size, and the colostrum corpuscles diminish further in number. After the fifteenth day, as a rule, we find no colostrum corpuscles; the milk is perfectly white and normal in appearance. The fat-globules tend to become more nearly equal in size, but vary in different subjects, however, during lactation.

MONTI[99] states that the colostrum corpuscles are usually present for about one week after labor, and that any considerable quantity at a later period denotes either disease of the mother or pregnancy. Jacobi[76] calls attention to the fact that excessive proteids are apt to cause gastro-intestinal symptoms during the colostrum period, particularly after premature confinement.

ADRIANCE[4] considers that the colostrum period covers the first two weeks of life. During this time we not infrequently find the fat percentage either very low or very high. The sugar content is lower than at any other time, but rises rapidly, ranging from 5.80 per cent. on the second day to 6.63 per cent. on the fourteenth day. The proteids pursue a contrary course, falling from 2.77 per cent. on the second day to 1.70 per cent. on the fourteenth day. The ash, like the proteids, is higher at this period than at any other. Examples of colostrum milk are cited to show the changes during the first part of lactation.

	Mother—twenty years.		Mother—nineteen years.		Mother—twenty-three years.	
	Three days.	Six days.	Two days.	Ten days.	Six days.	One month, seventeen days.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fat	4.52	2.80	3.77	2.64	4.30	4.08
Sugar	5.86	6.83	5.39	6.62	5.38	6.91
Proteids	2.37	2.13	3.31	1.70	2.79	1.44
Salts	0.26	0.25	0.27	0.23	0.23	0.19

Woodward,[249] in the *Journal of Experimental Medicine,* March, 1897, reports the results of the examination of six cases of colostrum milk at the Pepper Clinical Laboratory. He found the color yellow, the reaction alkaline, and the specific gravity from 1024 to 1034, depending on the amount of fat present, which varied from two to 5.3 per cent. The proteids ranged from 1.64 to 2.22 per cent. and the ash from 0.14 to 0.42 per cent., while the total solids varied from 10.18 to 13.65 per cent. The lactose (calculated) percentage was from 5.6 to 7.4. An average colostrum milk contains four per cent. of fat, 1.9 per cent. of proteids, 6.5 per cent. of lactose, and 0.2 per cent. of ash, making the total solids 12.5 per cent. and water 87.5 per cent.

Microscopical examination of the corpuscles by A. E. Taylor showed a small, irregular, but much degenerated nucleus. The protoplasm is more or less filled with large and small granules, only a few of which are stained by osmic acid. These granules will not stain with acid, basic, and neutral dyes; they show the characteristics of proteids in their reactions. The few granules which are stained with osmic acid are probably fatty. The most marked feature is the constant and excessive degeneration.

Composition of Mother's Milk.

Before discussing the elements which constitute mother's milk, it will be well to quote the average percentages of the different ingredients as they are given in some of the leading text-books.

In glancing over the tables, it at once appears that there are greater variations in the proteid content than in that of the other ingredients. Monti's maximum of five per cent. proteids must be considered an abnormally high figure.

Although variations in the fat and proteid content may occur at any period of lactation, it will be shown in the following pages that the composition of mother's milk tends to approximate a certain average after lactation has become well established.

	Baginsky.[5]	Monti.[90]			Holt.[69]	Rotch.[119]
		Max.	Min.	Aver.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Water	87–88.5	90.1	84.9	88.6	85.5–89.82	87–88
Solids	11.5	16.5	10.0	11.0	....	12–13
Proteids ...	1.7	5.0	1.2	2.7	1–2.75	1–2
Casein.....	1.2	....	....	....	....	....
Albumin ..	0.5	....	....	....	....	....
Fat.......	3.8-4.07	4.0	2.0	3.0	3–5	3–4
Lactose ...	6–7.03	7.0	3.0	5.0	6–7	6–7
Ash.......	0.2–0.21	0.2	0.1	0.20	0.18–0.25	0.1–0.2

Baginsky's table seems to be averaged from the figures of Lehmann and Hoffmann.

Monti's table is drawn from the figures of Pfeiffer, König, Hoffmann, and Johannessen.

Holt's table is based on the analyses of Pfeiffer, König, Leeds, Harrington, and others.

Rotch's table represents the analyses of König, Forster, Meigs, Harrington, and others.

Proteids.

The chief proteids in mother's milk are casein, lactalbumin, and lacto-globulin. That lactalbumin is present in mother's milk is maintained by Lehmann, Schlossmann, Bendix, Baginsky, Monti, Holt, Rotch, and others, whereas Pfeiffer and Duclaux deny its existence.

The proteids of mother's milk are partly in solution and partly in suspension (Rotch). The casein is in suspension by virtue of the presence of calcium phosphate, with which it is probably combined, while the lactalbumin is in solution and resembles serum-albumin (Holt, Monti). Schlossmann states that casein contains phosphorus, and that lactalbumin contains sulphur in soluble form. In his latest series of analyses Schlossmann estimates the average amount of total proteids in mother's milk at 1.56 per cent. In an earlier series of analyses he found that of the total proteids sixty-three per cent. were represented by casein and thirty-seven per cent. by lactalbumin. According

to Lehmann and Bendix, the total proteids equal 1.7 per cent., and the ratio of casein to albumin is as 1.2 to 0.5 per cent. Camerer asserts that older milk contains relatively more casein than albumin, and Monti confirms this statement. In the latter's opinion, during the first months of life the breast-milk is characterized by a high content in lactalbumin as compared with casein. With the advance of lactation the amount of lactalbumin diminishes very decidedly, so that in the last months the casein predominates. Schlossmann considers that this large proportion of soluble albumin is of great help to digestion, since the infant obtains a considerable part of the nitrogen he requires in a form in which it can be directly absorbed, whereas casein has to undergo complicated changes before it is ready for absorption. The presence of lactalbumin causes precipitation of the casein in much finer flakes, as does also that of the finely emulsified fat. On the other hand, Baginsky doubts whether a marked difference exists between casein and lactalbumin in regard to their digestibility and ease of absorption, since there is ground for the assumption that mother's milk is absorbed *in toto* by the lacteals,—that is, without special preparation. (It seems questionable whether the casein of mother's milk can be absorbed as such.—Editors.)

Monti says that during the first two months of lactation normal milk has a proteid content of from two to two and a half per cent. (Percentages above two after the first three or four weeks of lactation may be considered above the average.—Editors.) If the ratio of casein to albumin is altered, especially if too little fat (less than three per cent.) is present, such a milk will disagree. A proteid content below two per cent., or even down to one per cent., may agree with the child at this period, but the latter proportion is too low for proper thriving. Over three per cent. is abnormal and will disagree at any period of lactation. After the second month from one to one and a half per cent. of proteids is present, and such a proportion will suffice for the needs of the infant if the

fat percentage is normal. Below one per cent. of proteids, however, is always abnormal, and, even if the fat is normal in quantity, children will not thrive on such a milk.

Analyses of Proteids in Human Milk.

In 1895 JOHANNESSEN [75] published the results of his investigations of mother's milk, based on one hundred and fifty samples from twenty-five healthy women; they were between twenty and forty-six years of age, most of them living in the city and in needy circumstances. The analyses were made daily for months together in all but a few of the cases. Fifty cubic centimetres were drawn from each breast directly before and directly after nursing. Using the Kjeldahl method and the Hammarsten-Sebelien coefficient (6.37), he found that the total proteid content averaged 1.1 per cent. In ten exceptions it rose to 2.6 and 2.8 per cent. For the first six months the proteid average was 1.19 per cent., for the next six months 0.99 per cent., and after the first year 0.90 per cent. The difference between the nitrogen present in the form of casein, albumin, and globulin and the total nitrogen amounted to 0.025 per cent. nitrogen. This must be considered to represent extractives.

HEUBNER [169] gives, as the average proteid content after the first week, from 1.02 to 1.2 per cent., based on the analyses of Johannessen, Forster, F. R. Hoffmann, Camerer and Söldner, Munk, Finkelstein, Hirschfeld, and others. The results of Adriance's analyses [4] gave a proteid percentage of 1.95 up to the third week; from that time to the fifteenth month the proteid average was 1.11 per cent.

MEIGS'S [98] analyses of mother's milk, which included samples from forty women, gave a proteid percentage of 1.05. His samples were obtained at varying intervals after nursing. Only a small proportion represented the milk of individual cases, the remainder being the mixed milk of a large number of women.

BIEDERT [7] states that woman's milk has a proteid content,

reckoned as nitrogen, of from 0.85 to 1.72 per cent.; reckoned as proteid plus undetermined remnant, of from 1.11 to 2.65 per cent.; whereas the proteids of cow's milk, reckoned as nitrogen, may be put at from 2.8 to 3.3 per cent., and, reckoned as total proteid constituents, at from 3.08 to 3.44 per cent. The composition of each mother's milk has individual characteristics, especially as to its nitrogenous and fat content; hence it is absurd to regard the average of mother's milk as a model, and unjust not to set great weight on the quantitative relations.

For purposes of comparison let us examine PFEIFFER'S "Table of Human Milk Constituents at All Periods of Lactation, including Two Analyses of Colostrum" (one hundred analyses in all).[118]

	Proteids estimated as casein.	Fat.	Sugar.	Salts.
	Per cent.	Per cent.	Per cent.	Per cent.
First month (including colostrum)	2.9	2.7	5.7	0.23
Second month	2.0	3.3	6.3	0.18
Third month	1.9	2.7	6.4	0.18
Fourth month	1.7	3.9	6.6	0.15
Fifth month	1.4	3.6	7.3	0.19
Sixth month	1.5	2.7	6.8	0.23
Seventh month	1.5	3.2	6.8	0.17
Eighth month	1.6	3.3	6.3	0.15
Ninth month	1.5	2.4	6.6	0.16
Tenth month	1.7	4.2	6.2	0.14
Eleventh month	1.4	3.5	6.6	0.14
Twelfth month	1.7	5.3	6.0	0.16
Thirteenth month	1.6	2.9	6.6	0.15

Pfeiffer's analyses show that mother's milk contains in the first days after birth a high percentage of proteids and salts and a low fat and sugar content. During the progress of lactation the proportions of proteids and salts gradually decrease while the sugar increases; the fats vary constantly.

Schlossmann, Adriance, and Richmond confirm the latter statement. KÖNIG's table[99] of the average composition of mother's milk, based on two hundred analyses, may also be cited, although it cannot be considered, in the light of more recent investigations, to represent the correct proportions of casein to albumin. The percentage of salts given (0.31) is abnormally high.

		Per cent.	
Proteids	Casein	1.03	2.29
	Albumin	1.26	
Fat		3.78	
Sugar		6.21	
Salts		0.31	
Water		87.41	
Solids		12.59	

MAGNUS BLAUBERG.[13] In 1894 the results of LEHMANN'S investigations were published by Hempel.[167] This author found the average composition of woman's milk to be: casein 1.2 per cent., albumin 0.5 per cent., fat 3.8 per cent., milk-sugar six per cent., ash 0.2 per cent., water 88.5 per cent. Lehmann found casein to exist as a double salt of calcium casein with lime phosphate. Cow's milk casein contained 6.6 per cent. calcium phosphate and 0.723 per cent. sulphur, while mother's milk casein contained 1.09 per cent. sulphur and only 3.2 per cent. calcium phosphate; hence he concludes that the two caseins are not identical.

The proteid averages of König and Pfeiffer were considered the standard until 1894, when Heubner, in the Congress of Hygiene at Pesth, announced the results of Professor Hoffmann's (Leipsic) analyses. Hoffmann obtained a large number of samples from the same women, and his investigations covered a long period. He concluded that after the third week from delivery, milk varies little in its composition from month to month, and gives the following average: proteids 1.03, fat 4.07, sugar 7.03, and ash 0.21 per cent.

Söldner,[40] at Camerer's instigation, determined to subject previous methods of analysis to a rigid test. He found by a series of parallel experiments that the Kjeldahl method for estimating nitrogen was perfectly applicable to milk, and gave reliable results (agreeing in this with Munk, in opposition to Salkowsky, who states that the Kjeldahl method gives too low figures for casein). The analyses of mother's milk by Söldner were based on samples of the breast-milk taken throughout the day; the breasts were evacuated as completely as possible and the infants nursed during the night.

	Proteid values (Kjeldahl method).						
Time after birth.	N × 6.25.		According to Munk.		Proteid plus unknown extractives.		Unknown extractives.
	Per cent.		Per cent.		Per cent.		Per cent.
Colostrum, early	5.8		5.35		7.34		1.99
Colostrum, late	3.17		2.90		4.26		1.33
Fifth and sixth days	2.04		1.81		2.66		0.85
Eighth and ninth days	1.54		1.42		2.42		1.00
Ninth day	1.47		1.40		2.20		0.80
Ninth and eleventh days	1.74		1.61		2.03		0.42
Fourth, fifth, and eleventh days	1.69		1.56		2.27		0.71
Eleventh day	1.74		1.61		2.55		0.94
Twentieth and twenty-first days	1.36	Average, 1.05	1.11	Average, 0.95	1.61	Average, 1.12	0.50
Twenty-ninth and thirtieth days	1.13		1.04		1.39		0.35
Seventy-fourth day	0.95		0.88		0.86		0.02
One hundred and thirteenth day	0.95		0.88		0.94		0.06
Two hundred and twenty-ninth day	0.88		0.81		0.82		0.01

Camerer and Söldner conclude from this work that the commonly accepted values for proteids are too high. They

emphasize the high percentage of extractives during the first three weeks of life. Such substances are only sparingly found in cow's milk, except in colostrum; among them are traces of urea, hypoxanthin, creatinin, potassium sulphocyanate, and lecithin.

Camerer and Söldner give this average for mother's milk at the middle of the *second week:* sugar 6.5 per cent., fat 3.28 per cent., ash 0.27 per cent., proteids (according to Munk) 1.52 per cent., citric acid 0.05 per cent., unknown extractives 0.78 per cent.; total solids 12.40 per cent. The number of samples analyzed is not sufficiently large to establish an average for the whole period of lactation.

Carter and Richmond.[39] The table drawn up by these authors represents the average of analyses of ninety-four samples of human milk, taken almost entirely from women in the lying-in department of the Birmingham Workhouse Infirmary. With seven exceptions, all the samples were obtained at some time within the first month after delivery. In the majority of the cases two samples were taken, one before and one after suckling; the quantity drawn off is not stated. Most of the mothers were healthy and most of the children thrived.

For the purposes of analysis the Ritthausen method, slightly modified, was used. The results of the work may be considered to establish an average for the first three weeks after birth, since seventy-six out of the ninety-four samples derive from this period of lactation. Only four separate breast-milks were examined during the fourth week, but three during the second month, three during the third month, and one at nine and a half months.

	Per cent.
Water	88.04
Fat	3.07
Sugar	6.59
Proteids	1.97
Salts	0.26
Specific gravity	1031.3

The proteid average during the first six days of life was 2.25 per cent., for the first two weeks 2.05 per cent., and during the fourth week 1.72 per cent.; after that time it showed a gradual diminution throughout lactation. The same diminution was noticed in the ash,—from 0.30 per cent. in the first week to 0.26 per cent. in the second week, 0.22 per cent. in the third and fourth weeks, and 0.21 per cent. after one month. The sugar percentage showed a tendency to increase with the progress of lactation.

The greatest variations were observed in the fat content, the next highest in the proteid percentage, and the least in the sugar.

LEEDS,[166] on the basis of eighty analyses of human milk, using the Gerber-Ritthausen method, asserts that the proteid average in breast-milk is about two per cent. He considers that the proteids are the most variable constituent in human milk, the fat the next most variable, and the sugar the least variable. Each sample was taken from both breasts (the quantity obtained not stated), and twenty-six out of sixty-eight samples were taken from two to three hours after nursing, the remainder at intervals varying from five minutes to five hours after the child had nursed. Of the total number of analyses, forty-one cover the first month of lactation, six samples were examined during the second and third months respectively, three during the fourth and fifth months, and four during the sixth month and period following. This number of analyses is hardly large enough to establish an average for any period of lactation except the first month; we may, however, accept Leeds's proteid average of two per cent. as a reliable estimate for the first four weeks of life. Leeds found that the proteid content of human milk was highest at the beginning (over two per cent.) and became less with the progress of lactation; the sugar percentage was lowest in the colostrum period, but soon rose and remained pretty constant. The fat content is high in the colostrum

period, but falls after the tenth day; the salts are slightly in excess during the first ten days, but vary little during the remainder of lactation.

In January, 1897, JOHN and VANDERPOEL ADRIANCE [4] published the results of their analyses of the breast-milk of one hundred and twenty cases. All the mothers were healthy and of an average age of twenty-five years; sixty-five were primiparæ and fifty-five multiparæ. The breasts were not entirely evacuated for each analysis, but the sample was taken after the child had nursed for two minutes. The results of these analyses show wide variations in the fat content at different periods of lactation, a gradual and steady increase in the sugar percentage, and a gradual decrease in the percentages of proteids and salts. The Kjeldahl method was used.

Adriance computed that the average specific gravity during lactation was 1030, the average fat percentage 3.83, the average total solids 12.20, and the average amount of water present 87.80 (up to the eighth month). He found variations at different periods of lactation, shown in the accompanying table.

	Carbohydrates. Per cent.	Proteids. Per cent.	Ash. Per cent.
Second to fourteenth day.......	5.80–6.63	2.77–1.70	0.27–0.20
One month	6.68	1.58	0.19
Three months..................	6.72	1.44	0.18
Six months	6.78	1.25	0.16
Nine months...................	6.84	1.04	0.16
Twelve months.................	6.90	0.83	0.15
Fifteen months................	6.96	0.63	0.14

SCHLOSSMANN,[241] in the *Archiv für Kinderheilkunde*, Bd. xxx., 1900, emphasizes the importance of allowing a sufficient interval of time to elapse after the last nursing before obtaining the sample to be investigated; also the necessity of getting, for accurate results, as nearly as possible the same quantity of milk which the infant would have taken from the breast.

The following table represents the results of two hundred and eighteen analyses of mother's milk at different periods of lactation. The Kjeldahl method was used. The proportion of soluble albumin to casein was not considered.

No. of cases analyzed.	No. of days after birth.	Fat per cent.	Nitrogen per cent.	N × 6.25 per cent. = proteids.	Sugar per cent.	Calories per litre.
6	9–10	4.23	0.29	1.81	6.92	744
25	11–20	4.63	0.29	1.81	6.89	780
41	21–30	4.53	0.31	1.94	6.77	772
21	31–40	5.00	0.24	1.50	6.97	805
13	41–50	5.41	0.28	1.75	6.80	847
24	51–60	4.62	0.25	1.56	7.28	785
10	61–70	4.69	0.23	1.44	6.94	773
19	71–100	5.39	0.20	1.25	6.77	823
25	101–140	5.10	0.20	1.25	6.94	803
15	141–200	4.02 (4.74)	0.217	1.29	6.89	702 (769)
19	over 200	5.55	0.21	1.31	7.33	863
218						

The average values in mother's milk during the first seven months of lactation are as follows: proteids 1.56 per cent., fat 4.83 per cent., sugar 6.95 per cent., nitrogen 0.25 per cent., calories per litre, 782.

The results of these analyses show that:

I. The proteid percentage in mother's milk is very high in the first weeks after birth, diminishing after the thirtieth day. From the sixtieth day we observe a more decided and rapid fall in the proteid content. It is remarkable how uniform the composition of the milk remains after the seventieth day.

II. The variations in the fat content are much less regular. We see the fact again demonstrated that in mother's milk the infant obtains a food decidedly richer in fat than is present in any kind of artificial food. The fat of mother's milk is

usually well digested by the infant, even when it is excessive in amount.

III. There is no regularity in the variations in the sugar content. We find in the high fat and sugar percentage the characteristic prevalence in mother's milk of the non-nitrogenous over the nitrogenous substances.

IV. In such cases as were observed over a long period of time the composition of the milk approximated very closely to the average figures given. A low proteid percentage was constantly observed in the later months. Schlossmann found that the amount of milk secreted by a strong, healthy mother was rather in excess of that generally accepted. In a series of daily estimations, carried out for long periods of time, the quantity secreted varied from one thousand cubic centimetres to sixteen hundred cubic centimetres daily. Schlossmann thinks that it is more common for the nursing child to get too much than too little, since many women have a superabundance of milk. In cases in which the flow is very easy and rapid, the child may take in a few moments enough to fill the stomach.

ROTCH.[119] "Reasoning from the strong analogy which must exist between human milk and cow's milk, and being aware of the great variations which occur in the latter, we may assume that human milk is liable to vary considerably in its composition with different milkings." Our present knowledge of human milk is not sufficiently exact for the formulation of a table to show the composition of woman's milk at different periods of her lactation. "We must also understand that human milk of normal quality and proving to be equally nutritious to the special infants fed on it may vary considerably in the percentages of all its elements and in the combinations of these percentages. This fact is well illustrated in the following table, showing the analyses of fourteen specimens of human milk, all differing in the combinations of their different elements.

Human Breast-Milk Analyses.

(Mothers healthy and infants all digesting well and gaining in weight.)

	I. Per cent.	II. Per cent.	III. Per cent.	IV. Per cent.	V. Per cent.	VI. Per cent.	VII. Per cent.
Fat........	5.16	4.88	4.84	4.37	4.11	3.82	3.80
Lactose....	5.68	6.20	6.10	6.30	5.90	5.70	6.15
Proteids....	4.14	3.71	4.17	3.27	3.71	1.08	3.53
Ash	0.17	0.19	0.19	0.16	0.21	0.20	0.20
Total solids.	15.15	14.98	15.30	14.10	13.93	10.80	13.68
Water.....	84.85	85.02	84.70	85.90	86.07	89.20	86.32
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

	VIII. Per cent.	IX. Per cent.	X. Per cent.	XI. Per cent.	XII. Per cent.	XIII. Per cent.	XIV. Per cent.
Fat........	3.76	3.30	3.16	2.96	2.36	2.09	2.02
Lactose....	6.95	7.30	7.20	5.78	7.10	6.70	6.55
Proteids....	2.04	3.07	1.65	1.91	2.20	1.38	2.12
Ash	0.14	0.12	0.21	0.12	0.16	0.15	0.15
Total solids.	12.89	13.79	12.22	10.77	11.82	10.32	10.84
Water.....	87.11	86.21	87.78	89.23	88.18	89.68	89.16
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

"In a number of these cases, when one of the infants who was doing well on its own mother's milk was fed with one of the other combinations, it soon became sick, and had to be changed back to the one adapted to its digestion. Human milk may, then, be considered to represent not an especial food but a combination of foods, and its fat, sugar, proteids, and ash to represent these different foods. In other words, we find by experience that the digestive capabilities of infants differ just as do those of adults, and that nature provides a number of varieties of good human milk adapted to the varying idiosyncrasies of infants."

Variations in the proteid content of mother's milk may occur exceptionally, as follows:

From 0.6 –2.8 per cent.....(Johannessen[75]).
From 0.7 –4.5 per cent.....(Holt[69]).
From 0.85–4.86 per cent.....(Leeds[166]).
From 0.57–4.25 per cent.....(König[119]).
From 1.10–3.62 per cent.....(Twenty-nine analyses of the College of Physicians and Surgeons, New York, cited by Rotch[119]).

Fat.

Monti.[99] Fat as found in mother's milk consists of spherical bodies which refract powerfully. They are surrounded, by molecular attraction, by a layer of casein which prevents their agglutination. The earlier view that they were surrounded by an albuminous envelope has been controverted by more recent investigators, especially Quincke. According to Woll, each cubic centimetre of milk contains from 1,030,000 to 5,750,000 fat-droplets. Their size varies from 0.001 to 0.004 millimetres (Fleischmann), and from 0.0024 to 0.0046 millimetres (Woll).

In general we can distinguish three forms of fat-globules: (1) The very large. (2) The medium-sized, which generally constitute the chief part of a good milk. (3) Punctiform or finely granular.

On the basis of numerous personal investigations which correspond with the generally accepted figures, Monti finds that the normal fat content of mother's milk varies from two and a half to four per cent. Giarré and Biagini, from one hundred and forty-nine cases, obtained similar results. Below two per cent. and above five per cent. are abnormal. In the milk of anæmic and weakly women we often find a fat content of from one to one and a half per cent., and in such cases finely granular (Class III.) fat-droplets predominate.

The fats consist of butyric, caproic, caprylic, myristic, palmitic, stearic, and oleic acids. According to Ruppel, mother's milk is comparatively poor in volatile acids: of the non-volatile, oleic acid forms one-half; palmitic and myristic are in excess over stearic acid.*

Milk containing very large fat-droplets (Class I.) is apt to be very rich in fat (Fleischmann). These may be found in excess in the secretion of older women and of those who have nursed for a long period, also during menstruation and febrile disturbances. In watery milk, poor in fat, there may be a predominance of small corpuscles (Class III.).

The percentage of fat in mother's milk is subject to wide and constant variations throughout lactation. The average content is variously stated:

		Per cent.
Mendez de Leon	(after the third week)	4.14
Hoffmann	(after the second week)	4.00
Richmond	(for the whole period of lactation)	3.07
Pfeiffer	(for the whole period of lactation)	3.11
Johannessen	(for the whole period of lactation)	3.21
Lehmann	(for the whole period of lactation)	3.80
Adriance	(for the whole period of lactation)	3.83
Leeds	(for the whole period of lactation)	4.13
Schlossmann	(for the whole period of lactation)	4.83

Variations in the fat content of mother's milk have been given as follows:

	Per cent.
Adriance	1.31–7.61
Johannessen	0.63–6.65
Holt	1.12–6.89
Chemical Laboratory of College of Physicians and Surgeons, New York	1.12–5.02
König	1.71–7.60
Leeds	2.11–6.89

* For original, see E. Laves, Zeitschrift für Physiolog. Chem., Bd. xix., and W. G. Ruppel, Zeitschrift für Biologie, Bd. xxxi.

Richmond found that the composition of the fat in the early part of lactation was different from that towards the close of this period. This was seen by studying the volatile fatty acids. Where the secretion of milk is deficient, the fat may vary from one per cent. before nursing to four per cent. after nursing.

Sugar.

The percentage of sugar may fairly be stated to average from six to seven. Adriance emphasizes the steady slight increase in the sugar percentage during lactation, from 5.80 on the second day to 6.96 at the fifteenth month. Johannessen's average of 4.67 per cent. throughout lactation seems to be decidedly subnormal, while Meigs's figure of 7.40 per cent. exceeds the average.

	Per cent.
Pfeiffer	6.3
Leeds	6.93
Johannessen	4.67
Richmond	6.59
Lehmann	6.0
Meigs	7.4
Schlossmann	6.95
Adriance	6.56

Salts.

The majority of authors state that the average percentage of salts in mother's milk is 0.20. The proportion diminishes during lactation, according to Adriance, from 0.27 on the second day to 0.14 at the fifteenth month.

Abnormal variations may occur: from 0.13 to 0.37 per cent. (Leeds). Pfeiffer found a minimum of 0.09 per cent.; Richmond a maximum of 0.50 per cent. Among the most reliable analyses of the salts in human milk are those made for Rotch in 1893 by Harrington and Kinnicutt. Six quarts of milk were analyzed with these results:

	Per cent.
Calcium phosphate	23.87
Calcium silicate	1.27
Calcium sulphate	2.25
Calcium carbonate	2.85
Magnesium carbonate	3.77
Potassium carbonate	23.47
Potassium sulphate	8.33
Potassium chloride	12.05
Sodium chloride	21.77
Iron oxide and alumina	0.37
	100.00

This represents the form in which salts probably exist in milk.

A portion of the lime is united to the casein; the rest is combined with phosphoric acid as a mixture of di- and tri-calcium phosphates, which are kept soluble and held in suspension by the casein.

The phosphorus in woman's milk consists mainly of casein-phosphorus, nucleon, and lecithin; it is nearly all held in organic combination, whereas in cow's milk less than half of the phosphorus is in organic combination. Nucleon is the richest in phosphorus of the organic compounds in milk; WITTMAACK'S [186] investigations showed that one litre of cow's milk contained from 0.55 to 0.6 gramme, and one litre of woman's milk from 1.1 to 1.3 grammes of nucleon. Nucleon can unite with lime and fix it in chemical combination. The total phosphorus content of cow's milk is 1.5 grammes, over three times that of mother's milk, 0.47 gramme (SIEGFRIED [188]).

STOKLASA [187] found that one litre of cow's milk contained from 0.9 to 1.13 grammes of lecithin, whereas in one litre of human milk there were present from 1.7 to 1.86 grammes of lecithin. The same investigator found that one litre of woman's milk contained 0.44 gramme of phosphoric acid, and one litre of cow's milk contained 1.81 grammes of the same.

Of the phosphoric acid in milk, then, 0.153 is represented by lecithin in woman's milk and 0.091 in cow's milk; of the total phosphorus content in woman's milk, thirty-five per cent. exists as lecithin, whereas in cow's milk lecithin represents but five per cent. Lecithin contains from 3.84 to 4.12 per cent. of phosphorus; it is broken up by the process of sterilization into cholin, glycerin-phosphoric acid, and fatty acids.

Variations in Composition.

KOEPPE [168] emphasizes the fact that constant alterations in the composition of mother's milk occur from hour to hour and day to day. He suggests that the poor results often obtained from the use of carefully selected pure and sterilized milk are due to its uniform consistence, whereas nature's product shows constant variations.

Adriance's analyses show that the milk of primiparæ during the third month of lactation is richer in fats, proteids, salts, and total solids than average milk; the sugar percentage is less in the milk of primiparæ. In the milk of multiparæ at this time there is more sugar and less proteids and fat.

LEEDS [166] considers that lean women in good physical condition furnish a milk richer in albuminoids than those of over-robust habit.

The composition of milk before and after suckling varies, especially in its fat percentage. This is well shown by Carter and Richmond [39] in a table deduced from the observation of thirty-seven cases:

	Before suckling. Per cent.	After suckling. Per cent.
Water	88.33	88.04
Fat	2.89	3.18
Sugar	6.51	6.53
Proteids	1.99	1.99
Ash	0.28	0.26

Johannessen gives the following differences:

	Before suckling. Per cent.	After suckling. Per cent.
Water	....	....
Fat	2.77	3.94
Sugar	5.70	5.09
Proteids	0.98	0.95
Ash	....	....

Johannessen's maximum variation in the fat percentage was from 1.51 before to 4.01 after suckling. Forster found more marked differences:

	Fore-milk. Per cent.	Middle milk. Per cent.	Strippings. Per cent.
Water	90.24	89.68	87.50
Fat	1.70	2.77	4.51
Sugar	5.56	5.70	5.10
Proteids	1.13	0.94	0.71
Ash	0.46	0.32	0.28

Summary.

If we draw up a table representing the results of the most reliable series of analyses of mother's milk, we find that the variations are not very great, and that the figures all approximate to a general average. The high estimates for the proteids obtained by Pfeiffer, Leeds, and Richmond may be partly accounted for by the fact that the Ritthausen method, which they employed, gives uniformly high results; besides this, the majority of Leeds's and Richmond's analyses were of samples taken during the first three or four weeks of lactation (including the colostrum period), when all observers are agreed that the percentage of proteids is uniformly high. Pfeiffer, Leeds, and Richmond found that the proteid per-

centage diminished after the first month of lactation. On the other hand, the low estimates of the total proteids reached by Meigs and Johannessen are probably explained by the fact that most of their samples came from needy women in poor hygienic surroundings. The tables of Pfeiffer, Schlossmann, and Adriance are in accord in showing that the total proteids are high at first but soon fall, to maintain a fairly constant average during the height of lactation. According to Schlossmann, Adriance, and Söldner, the total proteids show a tendency to gradually diminish until (towards the end of the first year) they rarely exceed one per cent.

	Pfeiffer.	Leeds.	Johannessen.	Richmond.	Lehmann.	Meigs.	Schlossmann.	Adriance.
Number of cases..	160	80	25	90	40	43	218	120
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fat.............	3.11	4.13	3.21	3.07	3.8	4.28	4.83	3.83
Sugar...........	6.3	6.93	4.67	6.59	6.0	7.4	6.95	6.56
Proteids.........	1.94	1.99	1.10	1.97	1.7	1.05	1.56	1.30
Salts............	0.19	0.20	....	0.26	0.20	0.10	....	0.20
Water...........	88.22	86.73	....	88.04	88.5	87.16	....	87.80
Solids...........	11.76	13.26	....	11.89	11.70	12.83	....	12.20

On the basis of the first five tables quoted above, which he says represent the results of the most reliable analyses of human milk, Richmond estimates the following to be the probable mean composition of normal human milk after lactation has become regular:

	Per cent.
Water......................................	88.2
Fat..	3.3
Sugar......................................	6.8
Proteids	1.5
Ash..	0.2

The tables of Schlossmann and Adriance deserve special notice, since they represent the result of analyses covering the whole period of lactation and carried out by uniform methods.

Richmond's average must not be considered to represent anything more than a general mean. At all times of lactation analysis of the breast-milk will show greater or less variations, in the proteid and fat content especially. All that can safely be said is that one and a half per cent. of proteids constitutes a proportion which is very constantly found during the height of lactation. Variations above and below this figure are frequent, so that we may regard two per cent. as a high and one per cent. as a low proteid content in mother's milk. Over two and under one per cent. may be considered abnormal except at the beginning and end of lactation.

The presence of 0.5 per cent. of soluble proteids in mother's milk, in the form of lactalbumin and lacto-globulin, is now generally accepted. These substances represent from one-third to one-fourth of the total proteid content, they are readily digestible, and apparently are present in larger proportion during the first months of life, when the child's powers of assimilation are little developed.

The percentage of fat in mother's milk varies normally between three and four and a half. Below two and over five are abnormal. Fat is the most variable constituent in mother's milk; the proportion is not affected by the period of lactation. The fat of mother's milk differs from that of cow's milk in containing fewer volatile acids; it is also in a much finer state of emulsion, and is therefore easier of digestion.

The percentage of sugar is a very constant one, varying from six to seven. It is lowest during the colostrum period; from that time on it steadily increases throughout lactation. The average percentage of sugar at the height of lactation may be estimated as six and one-half. It is readily assimilated.

The percentage of salts averages 0.2. It is highest at first and diminishes steadily during lactation. In contrast to cow's

milk, nearly all of the phosphorus exists in organie combination.*

The ratio of the nitrogenous to the non-nitrogenous elements in woman's milk is about 1 to 7.6; in cow's milk it is 1 to 2.3.

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* Schlossmann has recently asserted that the previous methods of analysis to determine the phosphorus content of milk are open to grave objections, so that he is no longer prepared to state that an essential difference exists between mother's milk and cow's milk as regards the amount of organic phosphorus present. (See Edlefsen's article, Chapter III.)

CHAPTER III.

COW'S MILK.

PRACTICALLY, the secretion of the domesticated milch-cow has come into universal use for the artificial feeding of infants. As substitutes for cow's milk, mare's milk, goat's milk, and ass's milk have been recommended, especially the latter. H. von Ranke[124] states that ass's milk contains, according to the latest authorities, casein and albumin in the ratio of one hundred to eighty-one (Soxhlet and Scheibe); [casein 1.32 and albumin 0.34 (Richmond)]; fat about one per cent., sugar six per cent., and ash from 0.4 to 0.5 per cent. Notwithstanding its low fat content, it is well adapted for use in the first eight to twelve weeks of life, and experience has proved its value. The results obtained have been encouraging, especially in Paris, where it is largely used by the better classes (its price is one dollar a quart). The cost and difficulty of obtaining ass's milk have prevented its coming into general use; the same may be said of goat's and mare's milk.

REACTION.

Cow's milk has usually, when fresh, an amphoteric reaction. At times it may be feebly alkaline. With phenol-phthalein the reaction is always acid (Klimmer).

At ordinary temperatures milk soon becomes acid on standing.

SPECIFIC GRAVITY.

Allowing for differences of temperature of the milk when tested, Richmond finds that the specific gravity of the mixed milk of the herd rarely falls outside of the limits of from

1030 to 1034, with an average of 1032. This average corresponds very closely with those obtained by other investigators, with the exception of Leeds, whose figures are decidedly higher (1039.7), and Klimmer, who finds variations at a temperature of 15° C. of from 1027 to 1040.

Richmond.[121] The specific gravity is dependent on two factors: the amount of solids not fat, which, being dissolved in water, raise the specific gravity; and the fat, which, being lighter than water, lowers it.

"By removing the fat as cream (with a small proportion of the other constituents), the specific gravity of the milk is raised. By the addition of water, the specific gravity is lowered. The specific gravity has been, and is, largely used as a test to show the addition of water to milk; for the detection of large amounts of water in milk it has some value.

"As a preliminary test, estimating the specific gravity is of the greatest importance and should never be neglected; as an absolute test, it is liable to be greatly misleading. This is shown by the following facts.

"I. With milk of 1034 specific gravity at least ten per cent. of water could be added before it would be suspected by this test.

"II. If the cream were all removed from a milk of 1032 specific gravity we would have a product of about 1036 specific gravity, and an addition of rather more than ten per cent. of water would bring the specific gravity back to 1032.

"III. If to milk of 1032 specific gravity sufficient cream be added to raise the percentage of fat four per cent., the specific gravity will be found to be about 1028."

Mixed Milk.

Practically, all authorities are agreed in recommending the use of the mixed milk from a herd, in order to dilute the harmful products which may be present in the milk of a single cow.

Description.

By far the most satisfactory account of the composition and characteristics of cow's milk is to be found in H. Droop Richmond's "Dairy Chemistry."[121] According to this author, milk is essentially an aqueous solution of lactose, albumin, and certain salts, holding in suspension globules of fat, and containing casein in a state of semi-solution, together with mineral matters. The composition of cow's milk is given as follows, on the basis of two hundred thousand analyses (English):

	Per cent.
Water	87.10
Fat	3.90
Lactose	4.75
Casein	3.00
Albumin	0.40
Ash	0.75

Paul Vieth (for twelve years analyst to the Aylesbury Dairy Company) gives the average ratio between lactose, proteids, and ash in milk as 13 to 9 to 2. Richmond found this marvellously exact.

Variations in composition may occur in abnormal milk:

	Per cent.
Fat	from 2.79–10.5
Lactose	from 1.91– 4.66
Proteids	from 3.35– 4.58
Ash	from 0.76– 0.94

In England, where cows are milked twice a day, the evening milk is almost invariably richer in fat than the morning milk. When the interval between milkings is twelve hours, this is far less noticeable than when it is from nine to ten hours during the day and fourteen to fifteen hours during the night.

Colostrum contains less sugar, a fat very poor in volatile

acids, and a high amount of nitrogenous compounds which differ from those of normal milk.

At least four days should elapse after parturition before the milk is used, although the milk does not regain its normal composition before the lapse of from eight to fourteen days. As lactation advances the fat, casein, and mineral salts increase and the sugar decreases (the reverse of what occurs in human milk).

The English Society of Public Analysts requires the following standard in cow's milk: three per cent. by weight of fat and eight and a half per cent. by weight of solids not fat. These limits have been accepted as satisfactory by the great majority of analytical chemists in the country. Vieth has found that a bad season for haymaking is nearly always followed by a deterioration in the quality of the milk in the following winter and spring. Long periods of cold and wet or heat and drought—when the cattle are at pasture—unfavorably influence the quantity and quality of the milk. A limit of three per cent. fat is reasonable for the mixed milk of a whole herd; far more commonly the milk falls below the standard of eight and a half per cent. of solids not fat. For all practical purposes the triple standard of eight and a half per cent. solids not fat, 0.5 per cent. total nitrogen, and 0.70 per cent. ash may be adopted for the purpose of judging whether or not the milk is of genuine composition.

Composition of Milk.

	Langlois[38] (French). Per cent.	Soxhlet[90] (German). Per cent.	Leeds[93] (American). Per cent.
Fat................	4.0	3.69	3.75
Sugar..............	5.0	4.88	4.42
Proteids............	3.4	3.55	3.76
Ash	0.6	0.71	0.68
Total solids.........	13.0	...	....
Water	87.0	87.17	....

The composition of milk varies considerably, according to the breed of cattle. Mr. Gordon, of the Walker-Gordon Laboratory, has collected the results of over one hundred and forty thousand analyses, sixty thousand of which represent the milk of the American grade of imported cow and the common native.

	Durham.	Ayrshire.	Holstein.	Jersey.	American grade.	Common native.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fat	4.04	3.89	2.88	5.21	4.01	3.69
Sugar	4.34	4.41	4.33	4.52	4.36	4.35
Proteids	4.17	4.01	3.99	3.99	4.06	4.09
Ash	0.73	0.73	0.74	0.71	0.74	0.73
Water	86.72	86.96	88.06	85.57	86.83	84.14

"Leaving out the Jerseys' milk, the following represents very closely the average composition of cow's milk as the (American) physician has to do with it in infant feeding" (Holt).

Average composition of cow's milk (American):

	Per cent.
Fat	3.50
Sugar	4.30
Proteids	4.00
Ash	0.70
Water	87.00

Provided the cattle are healthy, Holt does not consider that any special breed should be selected for the purposes of infant feeding. As fat is the most variable constituent of milk, the determination of its percentage suffices for all practical purposes.

In a recent interview Henry Leffmann states that the composition of good milk is as follows:

	Per cent.
Fat	from 3.5–4.5
Sugar	from 4.7–4.9
Proteids	from 3.5–3.8
Ash	from 0.7–0.8

The composition of cow's milk as given by Droop Richmond can undoubtedly be accepted as an average of English dairies, in view of the large number of analyses it represents. Holt's figures vary from Richmond's, but have a more distinct value to the American physician because they represent what might be called an American average (one hundred and forty thousand cases). The principal differences between his figures and those of Richmond consist in the higher proteid percentages. The tables of Langlois, Soxhlet, and Leeds have been selected because they represent the work of reliable investigators: many other analyses might have been cited, but as no two of them are identical, their enumeration would serve no useful purpose. The fact cannot be emphasized too strongly that the milk of even large herds of cattle, much more the milk of a single cow, is apt to vary markedly from any average that can be established, owing to differences in the breed of cattle, the methods of feeding, the season of the year, etc. Secondly, no rational average can be deduced from any but a large number of examinations made under unvarying conditions and with unvarying methods. Finally, no average can be expected to do more than establish a mean which a good milk may reasonably be expected to approximate.

The figures of Holt may be accepted as such an average, but whether the milk of a given herd will resemble it can be determined only by analysis. The milk of a carefully fed herd varies very little from day to day, so that an occasional test is all that is necessary to be assured of the proportion of the different ingredients. It is a great advantage of certified milk that its composition has to satisfy a definite standard, so that we may know what percentages of the different elements we

are administering, especially the amount of fat present, which is the most variable ingredient in cow's milk.

The use of the strippings of cow's milk in infant feeding has been advocated by some authors. To illustrate the variations in its composition, the following table is appended:

Harrington's analyses: [37]

	Water. Per cent.	Solids. Per cent.	Fat. Per cent.	Ash. Per cent.
Fore-milk	86.66	13.34	3.88	0.85
Middle milk	84.60	15.40	6.74	0.81
Strippings	82.87	17.13	8.12	0.82

Richmond states that it is not unusual to find more than ten per cent. of fat in strippings.

PROTEIDS—ALBUMINOIDS.

Since the digestion of the albuminoids of cow's milk constitutes one of the greatest difficulties in the artificial feeding of infants, it seems advisable to discuss their physical and chemical properties at some length. The consideration of the other ingredients follows, while the various methods of preparing milk for the infant will be detailed in a later chapter.

RICHMOND.[121] "The curd of cow's milk produced by the addition of acid is found to consist of casein which is combined with phosphates of the alkaline earths. In human milk this is replaced by a similar albuminoid which is not combined with phosphates.

"Besides casein there is a second albuminoid called albumin. This differs from casein in not being precipitated by acids and in being coagulable by heat. Other albuminoids have been described in milk, but many of them are only decomposition products of casein or albumin, which were formed during the process adopted for the removal of the other albuminoids.

"Evidence has been adduced of a third albuminoid, lacto-globulin. This is coagulable by heat and precipitated by neutral sulphates, tannin, etc. Rennin does not coagulate it; it only occurs in traces, and it is not known whether it differs chemically from serum-globulin. The chief characteristic of lacto-globulin is its solubility in sodium chloride solutions, even when acidified.

"Traces of Storches' mucoid-proteid also exist in milk, and it is possible that traces of albumose are formed during the decomposition to which milk is prone; true peptone has been proved to be absent. The casein in milk is probably in the state recently described by Picton and Linder as pseudo-solution. This state is due to the existence of particles in solution which are not sufficiently large to settle under the influence of gravity, but which will interfere with the passage of light. They can be separated by electricity or by filtering through a porous jar. They also show that there is no sharp dividing line between crystalloids and colloids in solution, substances in pseudo-solution, and substances in suspension. In milk we have these four states represented: the fat is in suspension, the casein in pseudo-solution, the albumin in solution as a colloid, and the lactose in solution as a crystalloid. These four states are probably due to the size of the conglomerates of molecules or particles."

Properties of the Albuminoids.

"Our present knowledge of the albuminoids is far from complete, though much work has been done on the subject. This is due to the fact that it is extremely difficult to obtain these compounds in anything like a state of purity. The difficulty is still further increased by the peculiar behavior of casein in retaining calcium salts if once it has been brought into contact with them, as is the case in milk.

"The milk albuminoids are bodies of complex composition

containing carbon, oxygen, nitrogen, hydrogen, phosphorus, and sulphur. The way in which these elements are combined is not known. . . . The molecule of albuminoids is very complex, as is evident by their being indiffusible bodies. By the action of acids and certain enzymes—*e.g.*, peptase (pepsin)—they are resolved into simpler bodies which become more and more diffusible as the decomposition advances."

Of the various albuminoids existing in cow's milk we will describe those four of whose presence we have the strongest evidence: casein, lactalbumin, lacto-globulin, and Storches' mucoid-proteid.

"Casein is precipitated by saturating a solution with sodium chloride, magnesium sulphate, and ammonium sulphate. Globulin is soluble in a saturated solution of sodium chloride, but precipitated by magnesium sulphate and ammonium sulphate. Albumin is soluble in a saturated solution of sodium chloride and magnesium sulphate, but precipitated by saturation with ammonium sulphate, while Storches' mucoid-proteid is not in solution.

"Casein and globulin are precipitated by acids, while albumin (and globulin if much salt is present) is not so precipitated. Casein has the remarkable property of being acted upon by chymase, the enzyme of rennet, with the formation of an insoluble product. Albumin is coagulated by the action of heat, 70° C. being sufficient to precipitate a great portion. Casein (and globulin?) are removed from solution by filtration through a porous cell, while albumin remains dissolved. All three are soluble in alkalies and precipitated by tannin and phospho-tungstic acid and are insoluble in alcohol."

Casein.—"Casein has the property of forming an opalescent solution when dissolved in the least possible excess of sodium phosphate and a small quantity of calcium chloride is added; it gives then a solution having the appearance of milk. It is probable that milk contains casein in this form. Casein has a peculiar affinity for calcium salts, especially the phosphate.

"Analyses do not yield very concordant results, but the most probable composition of casein is as follows:

Carbon. Per cent.	Hydrogen. Per cent.	Nitrogen. Per cent.	Sulphur. Per cent.	Phosphorus. Per cent.	Oxygen. Per cent.
53.13	7.06	15.78	0.77	0.86	22.40"

Hammarsten's and Wroblewsky's analyses show the following differences between mother's milk casein and cow's milk casein:

	Carbon. Per cent.	Hydrogen. Per cent.	Nitrogen. Per cent.	Phosphorus. Per cent.	Sulphur. Per cent.	Oxygen. Per cent.
Breast-milk casein (Wroblewsky)	52.24	7.72	14.97	0.68	1.17	23.66
Cow's milk casein (Hammarsten)	53.00	7.00	25.70	0.85	0.80	22.65

Lactalbumin.—"This albuminoid has the property characteristic of albumins of being coagulated by raising the temperature of its solution to 70° C. The precipitation is never complete, since, according to Sebelien, as much as twelve per cent. may be left in solution."

He gives the following table of its composition:

Carbon. Per cent.	Hydrogen. Per cent.	Nitrogen. Per cent.	Sulphur. Per cent.	Oxygen. Per cent.
52.19	7.18	15.77	1.73	23.13

It differs from casein in containing no phosphorus and about twice as much sulphur. The amount of lactalbumin in cow's milk is variously estimated at from 0.3 to 0.5 per cent. by Lehmann, Klimmer, and other investigators.

Whey-Proteids.—When a solution of rennin is brought

into contact with cow's milk at a moderate temperature (from 90° to 100° F.) the casein is coagulated and the serous portion of the milk separates as a white translucent fluid called whey. This contains the whey-proteids, part of the salts, the sugar of milk, together with a small amount of fat. The whey-proteids comprise the lactalbumin and lacto-globulin of milk, besides a soluble proteid similar to albumin, which is split off from the casein by the action of the rennin (Leffmann).

Both Rotch and Cautley, by a series of experiments on the coagulability of milk with acetic acid, have endeavored to show that, in order to simulate the curd produced in mother's milk by the addition of acid, cow's milk must be diluted with from four to five times its bulk of water; or, in other words, that there is from four to five times as much caseinogen in cow's milk as in mother's milk. These results cannot be accepted as conclusive, for we know that coagulation by rennet is the first step in the digestion of casein in the infant's stomach; hence the natural conditions cannot be said to have been imitated in the test-tube experiments.

Fat.

Richmond.[121] "The fat in cow's milk is of complex composition. It differs from all other fats in that it contains compound glycerides, partly built up of fatty acids of low molecular weight. The general consensus of opinion at the present day among chemists is, that the fat-globules in milk are not surrounded by a membranous envelope, therefore there is a true emulsion. There is very little doubt that a layer of some sort exists, probably formed by a force similar to capillary attraction. Leeds says that this layer consists of a number of albuminous molecules which have been condensed by molecular attraction and thereby hinder the coalescence of the fat particles.

"From the mean results obtained by different observers, the average composition of the fat of milk appears to be as follows:

	Per cent.		Per cent.		Per cent.	
Butyrin..........	3.85,	yielding	3.43	fatty acids and	1.17	glycerol.
Caproin.........	3.60,	yielding	3.25	fatty acids and	0.86	glycerol.
Caprylin.........	0.55,	yielding	0.51	fatty acids and	0.10	glycerol.
Caprin...........	1.90,	yielding	1.77	fatty acids and	0.31	glycerol.
Laurin...........	7.40,	yielding	6.94	fatty acids and	1.07	glycerol.
Myristin.........	20.20,	yielding	19.14	fatty acids and	2.53	glycerol.
Palmitin.........	25.70,	yielding	24.48	fatty acids and	2.91	glycerol.
Stearin...........	1.80,	yielding	1.72	fatty acids and	0.19	glycerol.
Olein, etc.	35.00,	yielding	33.60	fatty acids and	3.39	glycerol.
Total........	100.00	Insoluble.	87.65	Total..	12.53	
		Total..	94.84			

"Besides the constituents enumerated above, there also exist traces of cholesterol (which doubtless replace a portion of the glycerol), lecithin, a coloring matter, and possibly also a hydrocarbon.

"Lecithin exists in small quantities in butter fat; on saponification it gives glyceryl-phosphoric acid, fatty acids, and choline; it contains 3.84 per cent. of phosphorus and gives 8.8 per cent. of phosphoric acid on oxidation. The quantity does not exceed 0.5 per cent. of the fat. There is also a coloring matter of unknown composition and an odoriferous principle."

Sugar.

"The sugar in cow's milk is said to be not identical with that in human milk.[121]

"Lactose is not fermentable by ordinary yeast and is not acted upon by invertase, diastase, rennet, pepsin, and trypsin. There exists, however, an enzyme called lactase, which is found in fresh kephir grains, which hydrolyzes lactose to glucose and galactose. The bacteria which decompose lactose with the production of lactic acid are acted upon inimically by acids, so that not much more than one per cent. of lactic acid is formed unless the solution is kept neutralized."

SALTS.

"The presence of citric and acetic acids in milk has not been universally accepted. Béchamp maintains that casein and albumin exist in milk as salts of alkalies. There is much to recommend this view.[121]

"Casein has a peculiar affinity for calcium salts, especially the phosphates, from which it is extremely difficult to free it; nor has it been found possible to dissolve casein to an appreciable extent without an alkali being present.

"Milk does not become sour until appreciable acidity has developed. The phenomenon of coagulation of milk after this has occurred, and on the application of heat, is probably due to the acid developed displacing the casein from its combination with an alkali, and, when this is wholly accomplished, to the free acid manifesting its properties. Söldner has also adduced evidence in proof of this view."

	HARRINGTON AND KINNICUTT. Ash of mother's milk. Per cent.	RICHMOND. Ash of cow's milk. Per cent.
Lime	15.69	20.27
Magnesia	1.92	2.80
Potash	24.77	28.71
Soda	9.19	6.67
Phosphoric acid	10.73	29.33
Chlorine	20.11	14.00
Carbonic acid	7.97	0.97
Sulphuric acid	2.19	a trace
Ferric oxide, etc.	0.40	0.40
Silica	0.70	....
Oxygen (calculated)	6.16	....
	99.83	103.15
Less oxygen and chlorine		3.15

Since by oxidation the phosphorus and sulphur of the proteids are altered into phosphoric and sulphuric acids, and the

carbon is changed into carbonic acid, the ash does not truly represent the mineral constituents of milk. About eight per cent. of the phosphoric acid present in the ash is derived from the phosphorus of the casein.

Comparison between the Salts of Mother's Milk and Cow's Milk.

Mother's Milk. Harrington and Kinnicutt.	Per cent.	Cow's Milk. Adapted from Söldner.	Per cent.
Sodium chloride	21.77	Sodium chloride	10.62
Potassium chloride	12.05	Potassium chloride	9.16
Potassium sulphate	8.33	Potassium citrate	5.47
Potassium carbonate	23.47	Potassium phosphate	21.99
Calcium phosphate	23.87	Calcium phosphate	16.32
Calcium carbonate	2.85	Calcium citrate	23.55
Calcium sulphate	2.25	Lime combined with proteids	5.13
Calcium silicate	1.27	Magnesium citrate	4.05
Magnesium carbonate	3.77	Magnesium phosphate	3.71
Iron oxide and alumina	0.37		

Leffmann considers that Söldner's table is in part theoretical.

Edlefsen.[244] While cow's milk is richer than mother's milk in phosphorus, only the smaller part of it is in organic combination in the former case. The remainder is present as inorganic phosphates. In woman's milk, on the other hand, all the phosphorus is in organic combination: according to Schlossmann, thirty-five per cent. in the casein, thirty-five per cent. in the nucleon, and thirty per cent. in the lecithin, as against thirty-five per cent. in the casein, eleven per cent. in the nucleon and lecithin, and fifty-four per cent. in inorganic combination in cow's milk. Since the casein contains phosphorus, it may be considered a nucleo-albumin; but whereas the nuclein contained in it is not absorbable as such, nucleon

and also lecithin are very easy of absorption. The organic phosphorus combinations are much more important for the nourishment and growth of the infant than the inorganic. According to the analyses of the fæces and urine by Rohmann and Steinitz, the administration of inorganic phosphates leads to an only slight gain in phosphorus. In the proportions in which cow's milk is given to the infant, there is only a small amount of casein and still less nucleon and lecithin. As far as the nuclein present in this small amount of casein is concerned, it can be completely absorbed. Nuclein, according to Popoff, and paranuclein, according to Gumlich, Sandmeyer, Micko, and others, are made soluble by the pancreatic ferments; for the most part, they are converted into nuclein-phosphoric acid. In this respect there do not seem to be any essential differences between cow's milk and mother's milk casein.

With regard to phosphorus metabolism, Paul Müller has shown that the absorption of the phosphorus of cow's milk, when not introduced in too large amount, is just as complete as that of the phosphorus in mother's milk (? EDITORS). Rubner and Heubner have demonstrated that the casein of cow's milk, if it is not given in excess, is as well absorbed as that of mother's milk (? EDITORS). But when diluted cow's milk is given, the amount of organic phosphorus present as well as that of the organic sulphur in the lactalbumin is very small. Up to the present we have found no means of compensating for the greater richness of mother's milk in nucleon and lecithin, which increases as the secretion of milk becomes more abundant. We know also that boiling destroys the lecithin (Baginsky), and if the application of heat is prolonged, also the nucleon; the nuclein of the casein is probably also modified. These facts perhaps explain why infants fed for a long time on milk and milk preparations which have been subjected for a considerable period of time to excessive heat (such as Scherff's, Hesse's, or Voltmer's Milk, Soxhlet's Mixture, etc.)

sometimes develop scurvy. The beneficial results from the administration of phosphorus and cod-liver oil in rickets make it probable that this disease is due, in great measure at least, to an insufficient amount of organic phosphorus in the food.

The diminution of the percentage of salts in mother's milk as lactation advances is compensated by the increased quantity of the milk secreted; so that the total amount furnished the infant suffices for its growth and especially for the bony development.

Gases.

Richmond.[121] The gases in milk have no practical importance. Oxygen, nitrogen, and carbon dioxide are present when it is fresh, probably due to absorption from the air during and after milking. On standing, the oxygen decreases and carbon dioxide increases, probably owing to aërobic bacteria.

Thörner[128] found that, directly after being drawn, cow's milk contained from fifty-seven to eighty-six cubic centimetres per litre of carbon dioxide, oxygen, and nitrogen. The serum of acid milk contains even larger amounts,—from one hundred and fourteen to one hundred and seventy-two cubic centimetres per litre. A large portion of this gas disappears in centrifugation; on the average, from twenty-seven to fifty-four cubic centimetres remain. Boiling and sterilization still further reduce the gas content to from fifteen to nineteen cubic centimetres per litre. By keeping in closed bottles an increase occurs, because, in bottles not heated directly after filling, carbon dioxide fermentation occurs. The unpleasant taste of milk sterilized in open bottles depends on the disappearance of carbon dioxide and not on chemical changes. If carbon dioxide can be incorporated artificially with such milk, the pleasant taste will return.

Separated Milk.

Richmond.[121] Skimmed milk contains from 0.4 to over two per cent. fat; in separated milk the limit of 0.3 per

cent. fat is rarely exceeded. By the removal of the fat the percentage of the other constituents is slightly increased.

By the action of the separator a slimy residue is left containing: (1) Inorganic impurities, such as dirt. (2) Vegetable matter derived from fodder, such as hay or leaves. (3) Substances derived from the cow, such as hair, pavement epithelium from the udder, empty gland cells (which form a very large portion of the slime), numerous micro-organisms, pus, blood, etc.

The quantity of slime equals 0.04 part in one hundred parts of milk separated; in dirty milk it may amount to 0.15 per cent.

The number of micro-organisms in cream and separated milk is not appreciably diminished by this process, and a mixture of them keeps no better than the milk from which they were separated. Straining through a fine wire sieve or through fine muslin or swan's down is usually practised. This removes the grosser impurities, but the amount of dirt removed in this way does not exceed 0.0025 per cent. Filtration through layers of gravel or sand is practised in some Danish, German, and English dairies; it has no advantage over the previous method.

Variations in the Composition of Cow's Milk.

Edsall.[50] In the course of metabolism experiments carried out at the Pepper Clinical Laboratory the author estimated the proteids of milk from one dairy for a period of ten months, using the Kjeldahl method. He found daily variations in the proteid content from 2.7 to 4.1 per cent. These occurred even in winter, when the cows were given regular fodder; in the spring, especially when the animals were fed largely on fresh grass, the daily variations were so great that calculations based upon any fixed percentage were liable to be very uncertain. It will almost always be found that the proportion of proteids is below the commonly accepted four per cent. In the same series of estimations the fat percentage varied from 3.2 to nearly six.

CHAPTER IV.

DIGESTION.

The digestive tract of the new-born and of the infant presents many features, both anatomical and physiological, in which it varies materially from that of the adult. The secretion of the different digestive ferments is slow in being established; in fact, it is only towards the end of the second or the beginning of the third year that the digestive functions approach in capacity those of the fully developed organism. It seems advisable, then, for the proper comprehension of the subject of infant feeding, to consider at some detail the anatomy of the digestive tract and the physiology of the organs of digestion.

Monti.[99] The salivary and parotid glands are small and poorly developed at birth, and the secretion of the salivary ferments, according to most observers, is slow in becoming established, not attaining decided power before the period of dentition. Soltau Fenwick [52] concludes, on the basis of numerous experiments, that the salivary secretions first have a decided and constant influence on starch about the fourth month, and Korowin found that at this time one and a half cubic centimetres of saliva appeared from five to seven minutes after taking food. On the other hand, Krüger asserts that he has found traces of ferment in the secretions of the salivary glands of a seven months fœtus (Monti and Baginsky). The parotid secretion contains more diastatic ferment than the other salivary glands (Zweifel and Korowin [99]). While ptyalin is found in the parotid at birth and in the submaxillary glands about the fourth week, the amylolytic action of these glands becomes fully established only towards

the end of the first year (MONTI,[99] THOMSON[143]). JACOBI,[76] on the other hand, states that the saliva possesses diastatic action after the first month, although its secretion is apt to be scanty in the very young and in cases of debility.

The truth of the matter would seem to be that the activity of the parotid and salivary glands varies in different infants. As a rule, however, the salivary secretions are not present in sufficient quantity to possess any considerable diastatic action on starchy substances before the fourth to the eighth month,—that is, about the period of dentition.

ANATOMY OF THE STOMACH.

MONTI.[99] The infant's stomach at first lies in an almost vertical position, and the fundus is poorly developed; Monti also lays stress on the slight degree of development of the greater curvature. Marfan and Thomson make similar statements. Thomson considers that the shape of the stomach is originally tubular. The capacity of the greater curvature stands in ratio to the capacity of the entire organ as one to five in the infant, whereas in adults it is as one to two (Moritz). According to Fleischmann, the layer of oblique muscular fibres is not present in the infant's stomach, nor are the long fibres described by Henle which radiate from the pyloric valve. The fibres at the fundus are the most poorly developed. Peristaltic movements increase in strength towards the pyloric end of the stomach and thus tend to approximate the cardia to the pylorus. Although the musculature is poorly developed, peristalsis will normally empty the stomach of its contents in from one and a half to two hours (Leo and Van Puteren); according to Biedert, in from two to two and a half hours. When digestion is difficult, the time required is longer and evacuation may be incomplete. Vomiting occurs easily, owing to the poor development of the fundus, the weak contraction of the cardiac sphincter, and the fluid consistence of the stomach contents (Monti). After ten months the mus-

cular coat of the stomach resembles that of adult life (Marfan).

The lab-glands are less numerous than in the adult stomach (Baginsky). Their form is funnel-shaped, and they are evenly distributed over the whole gastric surface. The multilocular glands are scattered, being most numerous at the pylorus; on the other hand, the mucous glands are more plentiful than in adult life; they are most thickly clustered at the pylorus and are least numerous at the cardia (Monti). The orifices and lumina of the gastric glands are greater than in adult life; the differentiation of the chief cells and the parietal cells occurs at different times in different subjects (Marfan).

Gastric Capacity.

Marfan.[105] The capacity of the infant's stomach is a variable factor, depending on the weight, the kind of food that is given, and the size of the child's body. Marfan has drawn up an average table based on the figures given by Beneke, Fleischmann, Frolowsky, D'Astros, and Zuccarelli. The capacity at birth is from forty to fifty cubic centimetres; at one month, sixty to seventy cubic centimetres; at three months, one hundred cubic centimetres; at five months, one hundred and fifty to two hundred cubic centimetres; from six months to one year, two hundred to two hundred and fifty cubic centimetres; at two years, three hundred and fifty cubic centimetres. These figures represent average values and enable us to determine the existence of dilatation of the stomach in the cadaver. They have also been used as a basis for the amount to be given at each meal in artificial feeding. We must not draw too rigid conclusions from these figures, for the capacity of the stomach is without doubt smaller in the living than in the cadaver. Besides, it has not been proved that it is necessary for a meal completely to distend the stomach. During nursing a portion of the milk ingested probably passes immediately from the stomach into the intestines.

	Fleischmann, Beneke, and Frolowsky,[99] from actual measurements.	Holt,[69] based on 91 cases.	Feer.[53]	Rotch,[119] from 341 cases fed at the Milk Laboratory.	Pfaundler,[225] based on 70 cases.
	Cc.	Cc.	Cc.	Cc.	Cc.
First day	40-45	36	....	29.4	...
First week	46–50	...	40–50	.....	...
Second week	70–72	45	80–90	.....	...
Third week	76–105	...	....	.....	...
Fourth week	100–122	60	85–110	70.5	90
Sixth week	....	68	....	.....	...
Eighth week	140–158	72	120–135	96.6	100
Tenth week	....	128	....	.....	...
Twelfth week	150–167	135	140	118.8	110
Four months	160–178	150	150	137.0	125
Five months	170–180	172	155	158.4	140
Six months	180–200	172	160	171.3	160
Seven months	....	206	....	185.4	180
Eight months	.. ....	206	.....	208.5	200
Nine months	....	...	....	226.2	225
Ten months	....	244	. .....	238.8	250
Eleven months	....	244	....	242.0	275
One year	300–400	267	....	.....	290
Two years	600–750	...	....	.....	...

Feer.[53] Examinations of the cadaver show a smaller gastric capacity than that commonly accepted; therefore it is not well to attempt to give to hand-fed children the maximum amounts which infants at the breast can take. The above table represents the average amount which babies at the breast will take. It should not be exceeded by children who are artificially fed.

Pfaundler [225] considers that the gastric capacity must not be compared with the age or the weight of the infant, since children of the same age often vary much in the degree of

their development, and since the change in the child's weight does not run parallel with the steadily increasing capacity. The correct standard of comparison, according to this author, is the length of the child's body, or, more accurately, the length of the trunk. From the study of seventy cases Pfaundler draws these conclusions:

I. The stomach of children at the breast is smaller than that of artificially fed infants.

II. Healthy infant stomachs have a smaller real capacity than those diseased either organically or functionally.

III. Large stomachs have little elasticity and distensibility, whereas the reverse is true of the small stomach.

Pfaundler found not a single instance of dilated stomach in children who were breast-fed; in artificially fed infants he found dilatation in twenty per cent.

We see, then, that the gastric capacity is a variable factor, depending on the rapidity of the child's growth, the kind of food administered, and the frequency of feeding. The figures of Feer and the measurements of Fleischmann, Beneke, and Frolowsky are high, and may be considered maximum amounts. The tables of Pfaundler, Holt, and Rotch probably represent the real capacity, while the figures based on measurements of the cadaver rather express the quantity of fluid which a fully distended or partially dilated stomach can hold. Since our knowledge of the anatomy of the infant's stomach teaches us that this organ readily dilates, and since clinical experience has shown that overfeeding (too large and too frequent meals) is only too common an occurrence, especially among artificially fed infants, the importance of carefully regulating the size and frequency of the meals cannot, in the light of our present knowledge, be overestimated.

Gastric Digestion.

Marfan.[105] Gastric digestion is accomplished by the gastric juice, which is secreted by the gastric glands and is composed

essentially of three substances: (1) lab-ferment, which coagulates the casein; (2) pepsin, a soluble ferment which renders the coagulum soluble and transforms it into peptone; (3) chlorine compounds, which unite with the casein in process of transformation, forming chloro-organic compounds analogous to amido-acids, and which can disengage free hydrochloric acid when this transformation is near its end. In the healthy infant's stomach free hydrochloric acid is absent, or only present in small quantity.

Casein is coagulated by the lab-ferment within fifteen minutes of its entrance into the stomach. This ferment is present already formed in the infant's stomach, whereas in the adult it exists in the condition of a proferment (a substance analogous to propepsin), which is converted into lab in the presence of a feebly acid solution. Since at the beginning of digestion the reaction of the gastric juice is neutral or feebly alkaline, coagulation of the casein is not due to the presence of acids. All the casein is coagulated by the lab; then a portion is attacked by the combined chlorides and the pepsin, liquefied and transformed into peptone (caseone or caseose), which is directly absorbable; another portion passes in a clotted condition into the intestine, where its digestion is achieved by the pancreatic juice. On the other hand, Hammarsten and Arthus and Pagès emphasize the differences existing between casein and albnmin with regard both to their solubility and their digestibility. The action of lab is to separate the soluble albumin from the clotted casein with its lime-salt combination. The albumin can be taken up directly by the gastric and intestinal mucous membrane (Brücke) and absorbed without undergoing further modifications; whereas the casein is digested principally in the intestine by the pancreatic secretions.

The subject of milk coagulation in the stomach has recently been thoroughly investigated by Joseph Schnürer at the Carolina Children's Hospital in Vienna.[131]

According to this author, two forms of coagulation occur:

(1) so-called acid precipitation (Arthus and Pagès), and (2) caseation or precipitation by lab-ferment (Arthus and Pagès).

1. *Acid Precipitation.*—In this case the casein does not exist as such, but in combination with lime. It only remains in this combination as long as there is present in the milk a mixture of mono- and di-phosphatic salts (especially sodium salts). When these salts are altered by the addition of some strong acid, a dissociation of the casein-lime combination occurs and the casein is precipitated. The clots resulting from acid coagulation are very fine, soft, and flexible, easily soluble in weak alkaline fluids, and can be curdled again in this fluid by the lab-ferment.

2. *Caseation or Precipitation by Lab-Ferment.*—In this process, according to Hammarsten, casein is split into two different forms of albumin,—paracasein and whey-albumin (called lacto-serum proteose by Arthus and Pagès).

This splitting up does not cause the precipitation of the paracasein, which first occurs when sufficient (from 0.02 to 0.5 per cent.) earthy alkaline salts are present in the fluid (calcium chloride being the best). The paracasein is then set free from its insoluble casein-lime combination. Caseation occurs in coarse lumps taking the shape of the test-tube. After standing the whey exudes as a discolored fluid in which the whey-proteid is recognized by its failure to precipitate with heat and acid. It also gives the biuret reaction after the other soluble albumins of the milk-serum, lactalbumin and lacto-globulin, have been removed. Dry paracasein is with difficulty soluble in alkalies. Freshly caseated precipitated paracasein, however, can be dissolved easily in a weak ammonia solution; it can be precipitated out of such solution by soluble lime salts (under certain conditions of temperature, etc.) and also by sodium chloride whether lime salts are present or not, but paracasein cannot be precipitated by lab-ferment out of its neutral or faintly acid solution, even in the

presence of soluble lime salts. This is the most important distinction between acid-casein and paracasein (Hammarsten, Escherich, Arthus and Pagès).

The presence of lab-ferment and of paracasein has been demonstrated by Arthus and Pagès in experiments on animals and with the stomach-tube in infants.

Whether caseation occurs or not depends on the amount of acid present. The presence of lab-ferment as well as hydrochloric acid in the stomach of the new-born infant has also been conclusively demonstrated by Szydlowsky, Schumburg, Boas, Johnson, Klemperer, Arthus and Pagès, Rosenthal, and Leo.

Biedert has shown that the fat of the milk acts by its enclosure in the lab clots so as to produce much finer curds, while Escherich finds that the fat, by hindering the spreading of the acid, delays its rapid action. The high degree of affinity of hydrochloric acid for cow's milk seems to be the reason why free hydrochloric acid appears late or not at all in the infant's stomach during digestion.

Lindenan, Walther, Escherich, and Arthus and Pagès agree that paracasein is more difficult of solution in the stomach than whey-albumin. It is also more resistant to pancreatic digestion, hence less well absorbed from the intestine (Escherich).

Marfan.[105] We know by the test-tube experiments that the casein of cow's milk clots in large homogeneous masses which are rich in fat and must be of difficult digestion; mother's milk, on the other hand, coagulates in fine flakes, poor in fat, which are without doubt more accessible to the action of the gastric juice. If we remove the gastric contents from a nursing infant half an hour after the meal, we find that the chyme is almost completely liquid and filters easily, while at the end of three-quarters of an hour casein clots are still present in the stomach if the child is being fed on cow's milk. We may conclude, then, that woman's milk is digested almost entirely in the stomach, but cow's milk only partially.

Half an hour after a meal the gastric contents show the presence of peptones, whether the child be sick or healthy, and whether it be fed on woman's or cow's milk (Toch). The casein of cow's milk, which is a nucleo-albumin, is broken up by the digestive juices into proteoses and nuclein or pseudo-nuclein (paranuclein, according to Knöpfelmacher, Wroblewsky, and Blauberg). During the course of digestion we find also ammoniacal compounds, leucin, tyrosin, and other by-products of albuminous digestion. Casein, then, is not only coagulated in the infant's stomach, but it is also liquefied and peptonized; this second part of gastric digestion is much more complete when the infant is nourished at the breast than when cow's milk is given.

The lactose undergoes in part lactic acid fermentation, and helps to bring about an acid reaction during the first fifteen or twenty minutes of digestion. The rôle of lactic acid in gastric digestion is not yet fully known; Biedert thinks that lactic acid can take the place of hydrochloric acid, of course less efficiently. Since the larger proportion of the hydrochloric acid unites with the casein and salts of the milk as fast as it is secreted, the presence of lactic acid (if this view be correct) would seem beneficial for the infant. Zotow,[105] on the other hand, considers lactic acid fermentation a sign of dyspepsia, since he was never able to find lactic acid in the stomachs of healthy children. Soltau Fenwick holds the same opinion.

It is supposed that the lactose not attacked by the microbes of lactic acid fermentation is absorbed as such, or is split up into glucose and galactose, which are directly absorbable. How this is accomplished is not yet definitely established, whether by the action of hydrochloric acid, or microbes, or of a special ferment (lactase). It is certain that the lactose is absorbed under one form or other almost entirely by the stomach; a minimal part is absorbed from the intestine.

The greater portion of the salts is absorbed by the stomach,

besides most of the water taken into the economy; von Mering alone asserts that the latter passes altogether into the intestine. The fats are not modified in the stomach; they enter the intestine either free or imprisoned in the casein clots.

We can divide gastric digestion into three phases. In the first, which lasts about half an hour, the lab-ferment coagulates the casein in the presence of a neutral or alkaline reaction. In the second the reaction of the chyme becomes acid; lactic acid is formed, and the casein unites with the chlorides of the gastric juice; in the third phase the stomach is emptied by peristalsis; then and then only do we find the reactions denoting the presence of free hydrochloric acid.

Hayem and Winter [105] made a special study of the chemistry of the gastric juice in infants. They conclude that:

1. The total acidity is feeble; it is due to lactic acid, and especially to hydrochloric acid in combination with organic matters and ammonia.

2. The total chlorides are small in quantity, which indicates either that the secretory apparatus is but slightly developed in the infant or that there is only a feeble response to the stimulus of milk entering the stomach.

3. After half an hour the digestion of a test-meal is about as advanced as it would be in the adult after one hour.

Marcel and Henry Labbé [108] have shown that:

1. In infants under two years the gastric juice never contains free hydrochloric acid during digestion.

2. The fixed chlorides exist in quite definite proportions; their quantity increases rapidly during the first months of life, to attain a maximum at one year and then decrease.

3. The combined chlorides and the total chlorides increase with the age of the child.

4. The total acidity, feeble in the new-born, increases very rapidly during the first months of life, owing to fermentation in the stomach; later it increases more slowly parallel with the combined chlorides.

Marfan.[105] We find a higher total acidity when healthy infants are fed on pure cow's milk; this acidity is due not to free hydrochloric acid, but to lactic acid (which is formed in greater abundance than when the infant is fed on mother's milk) and to combined chlorides, which are also present in larger quantities. The percentage of total chlorides is also higher; it reaches a figure at the end of three-quarters of an hour almost equal to that in the adult one hour after the test-meal. But the ratio of the total chlorides to the fixed chlorides is rather inconstant, sometimes higher and sometimes lower, indicating anomalies in the gastric chemistry which are in accord with the exaggerated elevation of α. $\alpha = \frac{A-H}{C}$. $A =$ the degree of total acidity; $H =$ free hydrochloric acid; $C =$ the combined chlorides. The elevation of α indicates an excess of acids of fermentation. These characteristics can be considered as the effect of a certain degree of gastritis with relative hyperpepsia and abnormal fermentations.

All authors are agreed in recognizing that free hydrochloric acid is absent from the chyme during gastric digestion of milk, whether the infant be sick or healthy; but there is disagreement on the question whether hydrochloric acid does not appear towards the end of digestion or after the evacuation of the stomach contents. According to Reichmann, Leo, Cassel and Heubner, Wohlmann, and A. Czerny, hydrochloric acid appears near the end of digestion or after the evacuation of the stomach contents. In breast-fed babies A. Czerny found hydrochloric acid in the stomach one and a quarter hours after taking food, to attain its maximum in from one and a half to two hours afterwards; in the artificially fed child hydrochloric acid appeared only about two hours after the meal. Einhorn and Hayem found no free hydrochloric acid. Thiercelin did not find free hydrochloric acid in healthy infants; it was, however, occasionally present in dyspeptic children.

The absence of free hydrochloric acid is explained by the fact that during digestion a large portion of it enters into

combination with the casein and phosphatic salts of the milk; this also shows why its appearance is longer delayed in the digestion of cow's milk.

Lactic acid is present during the first half-hour of digestion, and after that time hydrochloric acid (Uffelmann, Ewald, Boas). Heubner has estimated the quantity of lactic acid present to be from 0.10 to 0.40 per cent.

Bauer and Deutsch [17] have investigated the gastric secretions in a large number of children. Of these eight were infants, five under five months, three over five months old,—all of them healthy. The latter were fed on pure cow's milk, the former on pure cow's milk and water, equal parts. In from three-quarters of an hour to one hour and a half after food ingestion lactic acid was always found in large amounts; the total acidity was feeble. Free hydrochloric acid could not be demonstrated in the younger infants. In the three cases over five months of age they obtained from 0.06205 to 0.08395 per cent. free hydrochloric acid after from one and a half to two hours. They conclude that during the first months of life lactic acid predominates, especially at the beginning of digestion. During the second half of the first year the percentage of free hydrochloric acid increases and is approximately similar to that found in adults. The reaction of the empty stomach was found to be neutral or acid, the presence of secretion being due to irritation by the stomach-tube. The specific gravity of the gastric juice varied from 1005 to 1009. Experiments were made to determine the power and rapidity of absorption by the stomach. Potassium iodide was detected in the saliva in from four to seven minutes after its ingestion, and in the urine in from seven to fifteen minutes, somewhat earlier than is the case in adults, while the salol test gave positive results usually in from thirty to thirty-five minutes. Butyric and acetic acids could not be demonstrated.

The gastric secretions of three premature infants were also

studied; only minimal amounts of acid could be demonstrated. Lactic acid was always present, but free hydrochloric acid was not demonstrable. Wohlmann obtained similar results.

Nine healthy children, varying in age from two and a half to ten years, showed in the great majority of the cases the presence of free hydrochloric acid from one to one and a half hours after taking food; the quantity varied from 0.04015 to 0.12957 per cent. At the beginning of digestion lactic acid predominated, later hydrochloric acid. There was a marked antagonism between hydrochloric and lactic acids. The motor power and power of absorption of the stomach showed little variation from the conditions present in the adult. Lactic acid was found ten minutes after taking food; it increased in quantity during the next thirty to forty minutes, to disappear gradually with the appearance of hydrochloric acid. We have, then, three stages of digestion: (1) lactic acid alone, (2) lactic and hydrochloric acids both present, (3) hydrochloric acid alone.

In infants suffering from gastro-intestinal disorders the presence of free hydrochloric acid could not be demonstrated. Lactic and butyric acids were found in considerable, and acetic acid occasionally in smaller, quantity. Where the disease was confined to the intestines, free hydrochloric acid was sometimes present. Motility and absorption were much delayed.

Cohn investigated for the presence of free hydrochloric acid by Mintz's method in eighty cases; all of them were breast-fed and suffering from a variety of gastro-intestinal disturbances, of which eleven were acute and sixty-nine subacute and chronic disorders. Free hydrochloric acid could be demonstrated in only fourteen out of ninety-four investigations; the largest quantities found were 0.13, 0.1, and 0.062 per cent. The tests were carried out one and a half, two, and two and a half hours after nursing.

Wolf and Friedjung [157] have studied the secretions of the stomach in ninety-eight cases, varying in age from ten days

to twenty-one months, and suffering from various acute and chronic gastro-intestinal diseases. They conclude that the presence or absence of the normal secretions of the stomach is not a reliable test of the powers of digestion.

Bauer and Deutsch.[17] The views of authors are considerably at variance with regard to the kind of acid predominating in the infant's stomach during digestion. Biedert, Wohlmann, Moncorvo, and others consider hydrochloric acid the dominating factor; on the other hand, Heubner, Van Puteren, Massini, and others emphasize the presence of lactic acid. Generally they found hydrochloric acid present only in isolated cases; this must be ascribed (in accordance with Leo's statement) to the power of milk to combine with and neutralize acids.

Leo obtained a faintly acid reaction one-quarter of an hour after milk was ingested; at the end of digestion a small amount of free hydrochloric acid could sometimes be demonstrated. Van Puteren found after ten minutes' digestion a total acidity of 0.878 per cent., with maximum values of from one to 2.1 per cent. Von Jaksch, in a three-weeks-old infant, found a total acidity of 0.512 per cent. after one hour's digestion. Einhorn obtained an acid reaction after one hour, but could not demonstrate the presence of free hydrochloric acid. Heubner was able to determine quantitatively the presence of free hydrochloric acid after from one and a half to two hours' digestion in the great majority of his observations; in a less advanced stage of digestion he almost invariably found lactic acid present. Copolt determined the presence of free hydrochloric acid only exceptionally; in contrast to this, he found the total acidity to vary from 0.02 to 0.08 per cent. On the other hand, Wohlmann's figures for free hydrochloric acid are high. He found from 0.831 to 1.08 per cent. present in from one and a quarter to two hours after taking food. Marcel and Henry Labbé obtained the following figures at different ages, representing the degree of total acidity: in the new-born 0.03 per cent.; from one to six months 0.11 per cent.; from six

months to one year 0.13 per cent.; from one to two years 0.14 per cent.

W. SOLTAU FENWICK [52] instituted a series of experiments on healthy infants, some breast-fed, others getting cow's milk or farinaceous food. The tests were identical in method and the same quantity of food was given each time.

I. The amount of hydrochloric acid secreted varies in different children and in the same child from day to day and from meal to meal. In the stomach of nursing infants milk is usually curdled in from ten to fifteen minutes after its entrance, owing to the presence of lab-ferment in the gastric secretion. This is observed immediately after birth. The acidity of the gastric contents gradually increases during digestion, and attains its maximum in from ninety to one hundred and ten minutes after the commencement of the meal. The average total acidity is 0.02 per cent. at the end of ten minutes, from 0.06 to 0.075 per cent. at the end of one hour, and 0.13 per cent. at the end of eighty minutes. (N.B.—Ordinary methods of filtration reduce the acidity of the gastric contents, often by as much as 0.05 per cent.) Free hydrochloric acid is an inconstant factor, appearing usually after eighty minutes, or when the viscus is partially empty. Pepsin is invariably present so long as the secretion contains any trace of the mineral acids. Lactic and other secondary acids are not found in normal digestion, and must be regarded as evidence of fermentation.

II. When the infant is fed on cow's milk the total gastric acidity is greater, and may amount at the end of eighty minutes to 0.18 per cent. of hydrochloric acid. Free hydrochloric acid can usually be found near the end of digestion. In most cases lactic acid can also be detected, but never in any appreciable amount.

III. When the diet is farinaceous, the total acidity of the gastric contents is invariably diminished, and may not exceed more than half the normal. In a few cases eighty minutes

after giving oatmeal and water there was only faint acidity. The same children showed normal powers of secretion when given milk.

The quantity of gastric juice secreted bears a distinct relation to the kind of food and the size of the meal. The proteid elements of the milk seize on the free acids and fix them in a chemical combination. Pfungen has shown that one hundred grammes of milk can saturate 0.298 gramme of hydrochloric acid; Lüttke, that this combination is stable at high temperatures, and does not give the usual reaction of free acid. Free acid is not found until all the proteids have been saturated, hence appears late or not at all. Bacterial growth is thus not inhibited to any extent. Fenwick found that the stomach emptied itself at the end of one and a half hours (on the average) in breast-fed children and in those fed on cow's milk at the end of two and a quarter hours; in all cases the major portion of its contents disappeared within the first hour. About forty-five minutes longer were required to dispose of the last thirty to forty cubic centimetres. Peptone can always be recognized within half an hour of the ingestion of food, proving the stomach to be more than a mere reservoir.

After the food leaves the stomach there still remains a small amount of mucus and gastric juice, in which free hydrochloric acid can be recognized. Pfannenstill has shown by the salol test that the motor activity of the stomach is not less than in older children. Salicyluric acid appears in the urine within the normal time.

Summary.

It would appear from these rather discordant observations that during the early months of life the secretions of the stomach—namely, those of hydrochloric acid and pepsin—are deficient in quantity when compared with those of a healthy adult. Lab-ferment seems, as a rule, to be present in sufficient amount, but the hydrochloric acid combines with the albuminoids of the milk as fast as it is poured out, so that it is

only at the end of digestion, if at all, that we find free hydrochloric acid. Lactic acid, on the other hand, is present almost from the first, owing to the splitting up of the lactose furnished in the nourishment. While the secretion of hydrochloric acid seems to be sufficiently plentiful for the needs of the healthy breast-fed infant, it would seem that the artificially fed child requires more hydrochloric acid for the purposes of digestion, owing either to the greater saturating power for acids of the casein of cow's milk or to the greater preponderance of the albuminoids in the latter. Hence comes the greater frequency of gastric fermentation in bottle-fed babies, since the normal bactericidal action of the hydrochloric acid is feeble or absent. No standard can be formulated for the amount of free hydrochloric acid present normally during digestion; but it must be accepted as established that free hydrochloric acid is an inconstant factor, rarely found in considerable quantity. Lactic acid fermentation seems to be a part of normal digestion.

MARFAN.[105] The time of gastric digestion varies in different subjects and according to the kind of food given. Generally it may be said that in the healthy nursing child the stomach is emptied from one and a half to two hours after the meal; if the child is fed on boiled or sterilized cow's milk the time required will be from two to three hours; while raw cow's milk does not leave the stomach until four hours after its administration, according to Reichmann.

The muscular wall of the stomach is relatively thin during the early months of life and peristaltic movements are doubtless feeble in the new-born. But woman's milk, after the coagulation of the casein, remains almost liquid; it can be digested without being churned in the stomach; it is evacuated the more easily into the intestine since it is assisted by gravity, the position of the stomach being nearly vertical. When the child is nourished with cow's milk, the volume of the clots must increase the difficulty of peristalsis. This is doubtless

one of the causes of the tardy and imperfect digestion of cow's milk by the infant.

Intestinal Digestion.

The water which has not been absorbed by the stomach enters the duodenum in successive jets mixed with the mucus of the chyme. The casein leaves the stomach partly in the form of small clots but slightly modified, partly as syntonin, propeptone, peptones, besides compounds of chlorine and ammonia, fatty acids, leucin, tyrosin, and gases (chiefly carbon dioxide). Only a small amount of lactose enters the intestine; part of it has been absorbed from the stomach; probably part passes into the intestine as lactic acid. The fat is not modified as it leaves the stomach; a part is in suspension in the fluid, a part is incorporated in the casein clots. The salts which are not in solution are probably for the most part incorporated in the casein clots. The whole has an acid reaction as it enters the duodenum, where it is subjected to the action of the bile, the pancreatic, and the intestinal juices.

Anatomy of the Intestinal Tract.

Normally, the abdomen of the infant is rather prominent and voluminous; besides this, the lumbar spine is almost straight and not curved as in the adult (Marfan). The length of the intestinal canal is more than six times that of the body. Frolowsky states that the relative length of the large as compared with the small intestine equals in the new-born one to six, in infants one to five, and in the adult one to four. The muscular coat of the intestines is relatively poorly developed, peristalsis is irregular and inclined to be sluggish, and there is a tendency to dilatation of the abdomen (Monti). The duodenum forms a ring instead of the horseshoe curve of adult life (Marfan). It is proportionately longer than in adults, and its second portion constitutes a reservoir in which the bile and pancreatic juices can accumulate. The cæcum

lies high in the abdomen. The sigmoid flexure is very long, representing at birth nearly half the large intestine; it is very sinuous, and lies almost altogether outside the very narrow pelvic cavity.[105] We note in the anatomy of the intestines: the feeble development of the muscular wall, the relatively advanced development of the mucosa, especially of the lymphoid elements, the great vascularity of the villi, and the richness in nerves imperfectly myelinized.[105] Lieberkühn's glands are less numerous than in the adult; the mucous glands, on the contrary, are very plentiful and their secretion is copious.[99] Brunner's glands, though numerous, are in the early stage of their development.[105]

The development and vascularity of the villi and the almost complete evolution of the lymphatic tissues furnish conditions favorable for the absorption of chyle. Since the secretory apparatus is less developed, the food must be easy of digestion. The characteristics of the nervous tissues explain the readiness with which the intestines respond to causes of irritation and the ease with which this excitability becomes exhausted.[105]

Baginsky considers that the connective-tissue corpuscles of the mucosa form part of the lacteal system which begins at the terminal processes of the papillæ; they constitute, together with the large lymph-paths of the intestine, the real absorbent system (Baginsky). Histological investigation has shown that the absorptive power of the intestinal tract in infancy is essentially greater and more developed than that of adults, but physiological and chemical activity is less than in those of mature age because the glands are relatively poorly developed. On account of the extent and development of the absorbent lymph-paths, the intestine of the infant will easily absorb all the nutrient material which can be taken up without marked chemical change, whereas all food products which require marked chemical alteration can be utilized but slightly, if at all (Baginsky).

Marfan.[105] At birth the pancreas possesses its normal form and structure; its size is considerable; it weighs thirty-two grammes,—that is to say, $\frac{1}{100}$ part of the weight of the body; whereas in the adult it weighs from eighty to one hundred grammes,—that is to say, about $\frac{1}{600}$ part of the body weight. The pancreatic juice contains three ferments: trypsin, which in an alkaline medium transforms albuminoids into peptones; ptyalin or amylopsin, which saccharifies starch; and steapsin, which emulsifies the fats. Trypsin is present from birth and even during fœtal life (Albertoni, Langendorff, Hammarsten), but its secretion is scanty in the first weeks. Steapsin is also present from the first; not so the saccharifying ferment.

According to Korowin, amylopsin is absent up to the twentieth day, and only traces are present till the fourth month; from the sixth month the saccharifying power is definitely established. Zweifel found the pancreatic extract without power to act on starch up to the eighteenth day; Krueger obtained similar results in experiments on new-born animals. E. Moro claims to have found traces of the saccharifying ferment in the pancreas of the new-born. We may conclude that this ferment is absent or exists only in very small quantities during the first period of the infant's life. Since milk contains no starch, the young child has no need of this ferment; but one can readily understand the dangers of administering starchy foods to infants before the close of the first year. Zweifel states that in robust infants the trypsin ferment can digest albuminoids even in the first month; the power to split up neutral fats exists, however, only to a slight degree in infancy.

The liver is more voluminous than in the adult.

Bile forms the larger part of the meconium, and is present from the third month of fœtal life. The total quantity of bile secreted by the new-born and the infant is relatively more considerable than the amount secreted by the adult. During infancy the bile is deficient in fat, organic salts, and choles-

terin, and especially poor in biliary acids (Jacubowitsch, confirmed by Baginsky and Sommerfeld); mineral salts, except iron, are present in small amounts; bilirubin and biliverdin are abundant.

Bile does not seem to have any powerful influence on digestion, but it helps to hold the fats in emulsion. Its antiseptic power is feeble. The deficiency in biliary acids explains the inability of the infant to digest food too rich in fat, also the ease with which bacterial growth and intestinal putrefaction occur (if the other conditions are favorable).

Baginsky thinks that the deficiency in biliary acids favors pancreatic digestion, since the latter will not occur in too acid a medium. In the intestine cholesterin is neither absorbed nor modified, but is eliminated as such by the fæces. The biliary salts are decomposed in the intestine into amido-acids (taurin and glycocol) and a cholic nucleus (base). The former are reabsorbed almost entirely and returned to the liver; the latter is in part reabsorbed and in part eliminated by the fæces. Microbes probably are responsible for the splitting up of the bile salts, for in the intestine of the fœtus where germs are absent we find unaltered taurocholic acid (Zweifel). In the meconium before birth the normal biliary pigments are found in an unaltered condition, also a red pigment due to oxidation (Zweifel). In the intestine of the new-born and nursing infant there is only partial reduction of the normal pigments, so that we find at the same time bilirubin and hydro-bilirubin. In pathological conditions the stools contain a further product of oxidation,—namely, biliverdin (green stools).

The secretion of the intestinal glands is alkaline and possesses only feeble digestive properties. Its principal function is to alkalize the chyle and thus further absorption and increase peristalsis. Miura has found in the intestine of the fœtus and the new-born a ferment capable of converting cane-sugar; other authors claim to have discovered a saccharifying ferment,—namely, lactase. Moro discovered a diastatic enzyme

which was present in the intestinal contents and in the fæces, as a rule, directly after birth; during the first weeks of life it increased rapidly in quantity. This diastatic enzyme is secreted by the glandular organs of the intestine, and traces of the same can be demonstrated in the extract of pancreas of the new-born. Bacteria, on the other hand, have no share in its production. Woman's milk normally contains an enzyme of intense saccharifying properties, which is not present in cow's milk. This enzyme can be found in the fæces of nursing infants, and considerably increases their diastatic properties. Marfan has found a fat-splitting ferment (lipase) in mother's milk, which is very active. It is also present in cow's milk, but is less active.

When infants are nursed at the breast, the gastric chyme reaches the duodenum with portions of the casein transformed; its acidity is feeble, and the undigested clots are very fine, so that trypsin can act rapidly and easily. This ferment liquefies the coagulated casein and converts it into anti-peptone, which is absorbed as such, and hemi-peptone, which after prolonged pancreatic digestion is broken up into amido-acids (leucin, tyrosin, and hypoxanthine) and other by-products. When infants are fed on cow's milk, the digestion of casein in the stomach is much less advanced. The chyme is more acid and the clots larger and more difficult of penetration, so that the pancreatic digestion of the albuminoids is slow and imperfect.

Lactose enters the intestine partly as such, partly as lactic acid. The lactose may be absorbed as such, or may be split up by the action of micro-organisms into galactose and glucose, which can be directly absorbed. Others think that lactase is responsible for this change. Undoubtedly a portion of the lactose undergoes lactic acid fermentation in the intestines. When the fat reaches the intestines, part of it is free and a part is imprisoned in the casein clots and is freed from them by the action of trypsin. A small portion of the fat is split up into fatty acids and glycerin; the fatty acids combine with

the alkalies of the digestive juices to form soaps. This saponification, which is only feeble, has long been attributed to steapsin, but seems really to be due to the action of microbes. The sole function of the steapsin is to emulsify fats; emulsification is favored by the natural viscosity and alkalinity of the pancreatic juices, also by the presence of soaps and free fatty acids. The fat which is emulsified in very fine droplets is absorbed directly by the lacteals of the villi; the remainder traverses the intestine, undergoing natural saponification and microbic fermentation. In a healthy infant fed on mother's milk, rapidity is the distinguishing trait of intestinal digestion. After the passage of the chyme into the duodenum, its digestion is almost complete. Absorption takes place actively in the upper part of the small intestines, especially of the albuminoids, so that normally we find few traces of the latter in the lower part of the intestinal tract.

Senator considers that this rapid digestion and absorption explains the slight degree of intestinal putrefaction when the child is fed on breast-milk. We also know that the duodenum contains the fewest microbes; lower down, where they are more numerous, they do not find putrescible albuminoids to act upon. After the absorption of the food-stuffs the chyle consists principally of the following substances: biliary residues, whose destiny we know; amido-acids, various acids due to microbic fermentation; soaps,—products which are partly absorbed by the portal vein and transformed by the liver (thus leucin and tyrosin are changed into urea) and partly eliminated by the fæces; and a small quantity of neutral fats and acids which are passed with the stools.

With all this there still remain portions of the food substance not digested, which, with the other residues, are the prey of microbes and give rise to products of putrefaction, indol, skatol, phenol, ammoniac, and various toxins, which are also partially absorbed and transformed by the liver and partly eliminated by the fæces. The phenomena of putre-

faction attain their maximum in the large intestine, but normally they are never very considerable: witness the small amount of gas in the colon and the absence of fecal odor in the stools.

Summary.

Casein is only partially digested in the stomach, especially when cow's milk is the child's food. Pancreatic digestion plays the chief rôle in finally converting the casein into a form in which it can be absorbed by the duodenum and jejunum. Owing to the small amount of the gastric and the pancreatic secretions, the digestion of the proteids of milk (especially of cow's milk) is often imperfectly carried out during the first months of life. In the healthy breast-fed child the proteid residue is small and intestinal putrefaction is not a marked feature of digestion. The power to split up neutral fats is feeble during the first months of life; so also is the power to digest starch. Normally, a considerable portion of the fat is excreted in the stools. Milk-sugar is readily digested by the infant and normally leaves little residue. It seems probable, in the light of recent investigations, that the enzymes which have been found in the intestinal secretions and in mother's milk play a not inconsiderable rôle in the infant's digestive processes.

Experiments in Artificial Digestion.

The following conclusions were reached by J. H. Coriat [206] and A. S. Warthin [152] after a series of experiments with rennin:

1. Casein can be digested by both pepsin and pancreatin without being first coagulated by rennet. 2. When rennin is also present the amount of digested proteid or albumose proteid produced by the proteolytic enzymes is greater in every case. 3. The presence of rennin is necessary to secure a more rapid and energetic casein digestion. 4. The increased peptone production due to the presence of rennin takes place in both acid (pepsin) and alkaline (trypsin) media. 5. Only when

combined hydrochloric acid exceeds one-tenth of the bulk of the milk used will it coagulate milk, but not as rapidly as free hydrochloric acid. 6. Rennin coagulates milk without hydrochloric acid; but when the latter is present in combined form, and equal to one-tenth or less of the bulk of the milk used, coagulation takes place in a much shorter period of time. 7. The presence of acid-albumin hastens coagulation by the enzymes. 8. The time of coagulation decreases steadily as greater amounts of absolute rennin are present. 9. Vegetable enzymes coagulate milk in a way which compares favorably with rennin, and coagulation takes place under the same conditions as to temperature, acidity, and quantity present as rennin. 10. Enzymes exist in the plant kingdom which have an action analogous to that of rennin.

Rennet.

Richmond.[121] Rennet acts on casein only in neutral or acid solution. The optimum temperature is 41° C. (105° F.), the curd being firm. At a low temperature (15° to 20° C.) the curd is quite soft and flocculent, and at 50° C. the curd becomes very soft. The larger the amount of acid present the greater is the rapidity of its action on milk. The addition of water to milk causes it to be acted upon more slowly by rennet and the curd is less firm. By heating milk the action of rennet is delayed, owing to the removal of some of the soluble calcium compounds. By adding soluble lime salts the milk will be curdled in the usual manner.

Excretion.

Defecation.[105]—In the new-born and in the infant the muscular wall of the intestine is poorly developed and peristaltic movements are feeble. Zweifel has remarked that in the fœtus the intestinal contents move with extreme slowness; in a fœtus of three months the ileum and colon are empty; it is only at the end of the fourth month that the cæcum contains meco-

nium; the colon does not contain meconium before the fifth month.

After birth, when food is introduced and the secretion of the digestive juices becomes established, peristalsis becomes more active; the progress of food through the intestinal tract, however, is due perhaps more to a certain *vis a tergo* than to the influence of the still feeble peristaltic movements. It has been calculated that the chyle takes six hours to traverse the intestinal tract.

A healthy child usually has three or four evacuations daily during the first month of life, two or three a day for the next five or six months, and one or two a day during the remainder of the first year and the second year. Divers causes contribute to bring about this frequency in the evacuations. The principal factors are the large number of meals, the relative abundance of food, and the resulting relatively more considerable proportion of fecal material. Other factors are the semi-liquid state of the fæces and the feebleness of the anal sphincter. We must not forget that while the muscular coat of the intestine is little developed at birth, its reflex excitability is greater in the new-born and in the infant, since the still imperfectly developed cerebrum does not restrain the functions of the cord, whose evolution is more advanced.

The **meconium** may be brown, green, or black in color. It consists principally of epithelial cells from the intestinal mucosa, mucus and biliary secretions and pigments, chlorides and alkaline sulphates, a very small amount of phosphates and a minimal amount of iron (Guillemonat), leucocytes, cholesterin and hæmatoidin crystals, and grayish and fatty granulations (débris), probably from the amniotic fluid swallowed. There is none of the habitual products of putrefaction until postnatal infection has occurred. Meconium is usually evacuated within from six to twelve hours after birth, and is absent after the first two or three days. The total amount averages seventy-two grammes (Depaul).

The amount of **fæces** excreted by the infant is greater in proportion to the body weight than in the adult, on account of the relatively greater amount of nourishment which the former takes. According to Uffelmann, an infant at the breast excretes daily three grammes for each kilogramme of body weight,—about three per cent. of the nourishment taken; whereas the infant fed on cow's milk excretes from four to five per cent. daily (Monti).

Michel[105] found that an infant at the breast less than one month of age, and taking half a litre of milk a day, expelled daily, on the average, fifteen grammes of liquid fæces or three grammes of dried fæces. In the succeeding months this can rise to eighty grammes. The adult passes, on the average, one hundred and seventy grammes daily.

Towards the end of the first week the stools of the healthy breast-fed infant become of normal golden color; up to that time they have a greenish tinge. Even under normal conditions the fæces of healthy children contain at times yellowish-white masses. These do not consist of casein, as used to be thought, but are mainly made up of fat. Their consistence is that of a soft, semi-liquid paste, which, while it is favorable for absorption, also renders autointoxication more easy. The odor of the stools is not distinctly fecal, but resembles that of sour milk, and is not especially offensive. In healthy breast-fed infants the reaction of the stools is feebly acid, due to the presence of lactic and acetic, perhaps also butyric and valeric acids, which come from the fermentation of lactose. These acids must exist in considerable amount, since they are capable of neutralizing the alkalinity of the normal intestinal secretions. It has been suggested that they prevent the putrefaction of albuminoid substances.

In the new-born infant the pigment of the fæces consists principally of bilirubin. Wegscheider has found traces of urobilin (hydro-bilirubin), though Zweifel and Hoppe-Seyler deny its presence. Wegscheider found at times biliverdin

(Monti). Blauberg [13] also found both urobilin and biliverdin. He states that the stools may acquire a green color (due to biliverdin) after exposure to the air for some time. On the other hand, Pfeiffer rejects Zweifel's view that increased acid formation or the atmospheric oxygen gives rise to this greenish color, and considers that alkalinity which is furthered by bacterial development is responsible for it. Hayem and others have found bacilli which produce a green color. Blauberg thinks that not improbably ferments share in producing it.*

Marfan.[105] Infants' stools contain from eighty to eighty-five per cent. of water (Blauberg gives from seventy-five to eighty-five per cent.). The dry residue consists of food remnants, intestinal secretions, and bacteria. Faint traces of peptone are present (Blauberg, Wegscheider, Uffelmann).

Uffelmann has maintained, in opposition to Wegscheider, that at times leucin and tyrosin are found. The absence of products of putrefaction in normal digestion helps to explain the feeble toxicity of the fæces (Bouchard). Indol is ordinarily absent, but it may be present, as well as skatol and phenol (Uffelmann, Blauberg). Oxyacids are always present (Winternitz, Blauberg). Blauberg finds that small amounts of lactose are present during the first week of life. Marfan, on the other hand, states that there are no traces of sugar in the fæces, but merely the products of fermentation of lactose, especially lactic, acetic, butyric, and valeric acids. The presence of acetic acid seems highly probable (Blauberg), since Baginsky has demonstrated that lactose is decomposed in the intestine into acetic

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* The analyses of fæces published by Wegscheider in 1875, in his treatise "On the Normal Digestion of the Infant," were as follows: one hundred parts of fæces contain: water, 83.13 per cent., organic matter 13.71 per cent., salts 1.16 per cent. Ten analyses of the solids gave 3.39 per cent. for mucin, epithelial débris, and lime salts, aqueous extractives 5.35 per cent., alcoholic extracts 0.82 per cent., cholesterin 0.32 per cent., mineral salts 1.36 per cent., fat and fatty acids 1.44 per cent.

and carbonic acids, methane, and water. The small amount of gas in the intestines is almost odorless, or smells weakly of butyric acid. It consists of carbon dioxide, nitrogen, hydrogen, and methane.

Fat constitutes the major part of the infant's fæces. It is present as globules of neutral fat, crystals of the fatty acids, and especially lime soaps (oleate, palmitate, and stearate of lime). The amount of fat in the dried stools varies much, according to different investigators. Wegscheider placed it at from nine to twelve per cent., Biedert at ten to twenty per cent., Bendix at fourteen to twenty per cent., while Heubner considers twenty-five per cent. the maximum. Tschernow gives twenty to thirty per cent. and Michel twenty per cent. as the average. The large amount of fat not assimilated is remarkable. It would certainly seem as if the presence of an excess of fat, of which only a part is absorbed, is essential for the normal digestion of mother's milk.

Blauberg found for the first week of life that the mineral substances amounted to thirteen and a half per cent. of the dried fæces. About half of these are soluble in dilute hydrochloric acid.

The lime salts amount, on the average, to 15.31 per cent. of the soluble ash. The phosphoric acid varies from ten to thirteen and a half per cent. Considerable amounts of lime are in combination with organic acids.

According to Uffelmann, from twenty-nine to thirty-one per cent. of the fecal ash and ten per cent. of the dried residue consist of lime, besides which potash, soda, chlorine, and sulphuric and phosphoric acids are present. A portion of these minerals was originally present as carbonates and soaps.

Uffelmann [161] investigated the fæces of nine children, all at the breast and getting no other food, varying in age from one week to one year. He found a small amount of albuminoids, fat, free fatty acids, soaps (especially earthy soaps), potash, soda, lime, magnesia, and iron salts, united to hydrochloric,

sulphuric, and phosphoric acids, and organic acids, besides mucus, epithelia, cocci and bacilli, hay bacilli, biliary coloring matter (altered and unaltered), cholalic acid, cholesterin, and at times leucin and tyrosin. The water content was much more considerable than that of adult fæces; next to water, the chief constituents, reckoned according to their weight, were the masses of bacteria, mucus, and epithelium, next the fat and fatty acids, and finally the salts. Of fifteen parts of solids in one hundred parts of fæces, one and a half are inorganic, thirteen and a half organic; of the latter, fat and fatty acids constitute from two to three parts, there are traces of proteids up to 0.2 part and cholesterin up to 0.2 part; of the remnant, from eight to eight and a half parts consist of bacteria, mucus, and epithelial cells. The fæces never show a uniform proportion in their different ingredients.

Blauberg [13] found cholesterin always present, also lecithin, but only in minute amounts. Paul Müller [194] also found a small amount of lecithin uniformly present. Bile acids are present in small quantities; Jacubowitsch denies that glycocholic acid is present, but Baginsky states that he has found it.

Blauberg's tests for nucleins in the fæces of breast-fed infants resulted negatively, but he was able to demonstrate them in the fæces of artificially fed children. While Knöpfelmacher could detect no albumin remnant in the fæces of breast-fed infants, Blauberg finds that, as a rule, albumin is present in minute amounts during the first week of life. These may become considerable if there are digestive disturbances.

Biliary residues are abundant; the following ferments have been discovered: a saccharifying ferment (Wegscheider, Moro), an inverting ferment (Jacks, Miura), and a peptonizing ferment (Baginsky).

There are normally present a small amount of mucus and hosts of bacteria.

Marfan.[105] The fæces of an infant fed on cow's milk (even if it is sterilized, and especially if the milk is given undiluted)

are noticeably different from the evacuations of the nursing infant. They are firm, pasty, somewhat dry, and of a pale yellow color with a feebly ammoniacal odor. After evacuation their color at times turns gray (Uffelmann), whereas the stools of breast-fed infants are apt to assume a greenish hue. The reaction of the stools is generally alkaline or neutral; at times it is feebly acid. The alkalinity results either from ammoniacal fermentation or from the excess of mucus which is apt to be present owing to a slight degree of catarrh. Blauberg found lactic acid, fatty acids, and iron in decidedly larger quantities in the fæces of the breast-fed than of the bottle-fed infant. Indol is more frequently present in the evacuations of artificially fed infants (Uffelmann).

To conclude, the fæces of an infant fed on cow's milk contain more proteids (nucleins), fat, lime salts, and phosphoric acid, and less iron, and they are more copious relatively to the amount of food ingested than is the case in breast-fed infants.*

Biedert.[7] Under the microscope casein appears as finely granular masses; the fat-droplets resemble mother-of-pearl, and are scattered through the fæces in moderate quantity. These run together into larger drops in the evacuations of young breast-fed infants and when there are digestive disturbances. We also find fatty acid crystals and salts of the fatty acids which are either star-shaped or arranged in clusters, or form glistening yellowish amorphous clumps. Mucus appears as hyaline delicately folded bands, which run through the field, often with round cells or blood-cells sticking to them. Many bacteria are present.

Biedert gives the following directions for the examination of fæces. If proteids are present in the form of whitish lumps,

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* Knöpfelmacher [87] in 1899 investigated the so-called casein flakes in the fæces of dyspeptic infants fed on cow's milk, and found that they contained from 2.988 to 3.53 per cent. nitrogenous material, twenty-five to forty per cent. fat, and 18.08 per cent. ash (the fæces were dried on the water-bath, hence not free from water).

the specimen should be diluted with distilled water in a test-tube, after which Millon's reagent should be added. If the masses consist chiefly of proteids, they will form reddish lumps; if they are mingled with any considerable quantity of soaps or salts, the latter will become soluble and the solid masses or lumps will disintegrate. If the fluid is heated, an excess of fat can be recognized by the presence of fat-globules. Under the microscope these white lumps are recognized by their finely granular consistence; they are structurally similar to milk-clots, and enclose fat-droplets within the finely granular casein. Fine waxy threads of mucin enclosing mucus cells in their meshes are to be seen, and must be differentiated from the above.

Absorption.

Marfan.[105] The amount of food absorbed and assimilated by the infant fed on cow's milk is estimated at ninety-three per cent. instead of ninety-six per cent. for the breast-fed infant. The percentage of casein absorbed by the breast-fed infant is given by Michel as from ninety-four to ninety-nine per cent. According to the researches of Raudnitz, Lange, Bendix, Grosz, Lange and Berend, Knöpfelmacher, Keller, and Michel, the proportion of nitrogenous matter absorbed by the intestine in infants fed on cow's milk is very variable, but generally less than that found in nursing babies; it varies between ninety-three and seventy per cent. If the child suffers from digestive disturbances, the amount will be still lower. Where there is no digestive disturbance, the utilization of lactose will be about the same in the breast-fed and the artificially fed infant; but the absorption of mineral salts, especially of lime and phosphoric acid, is decidedly less complete in the bottle-fed infant. Biedert emphasizes the importance of the form of emulsion in which the fat exists: the finer it is the better will it be absorbed. The proportion of fat absorbed varies from ninety to ninety-eight per cent.; it is always higher in the breast-fed infant.

The Stools in Pathological Conditions.

Abnormal types of stools may be classified, according to Chapin,[201] as follows:

I. *Green Stools.*—Stools can only be considered green when that condition is evident immediately upon their passage. The color is due to fermentation, which doubtless results from bacterial action. All stools become green a certain time after passage, causes by oxidation of the air.

II. *Curdy Stools.*—Curdy lumps may be produced by undigested casein or fat. The former are hard and yellowish, while the latter are soft and smooth like butter.

III. *Slimy Stools.*—These are the result of catarrhal inflammation. When the mucus is mixed with fecal matter, the irritation is high up in the bowel; but when flakes or masses of mucus are passed, the trouble is near the outlet.

IV. *Yellow, Watery Stools.*—These are seen in depressed nervous conditions, especially in the hot days of summer, when the bowel is relaxed and the inhibitory fibres of the splanchnic nerves do not act to advantage.

V. *Very Foul Stools.*—These are caused by decomposition of the albuminoid principles of the food.

VI. *Profuse, Colorless, Watery Stools, with Little Fecal Matter.*—These are doubtless caused by an infective germ akin to that of Asiatic cholera. This condition is known as *cholera infantum.*

These types are rarely seen alone, but are frequently found in all sorts of combinations (except the last).

CHAPTER V.

MODERN METHODS OF INFANT FEEDING.

The views of the leading pediatrists of Germany, France, England, and the United States differ more or less widely on the subject of infant feeding, yet certain general principles may be evolved from their teachings. Short abstracts of the views of Biedert, Monti, Baginsky, Holt, Rotch, and other prominent teachers abroad and in this country have been prepared that the reader may learn how great a variety of methods have been advocated for the artificial feeding of infants.

Biedert [7] advises that cow's milk should be diluted three or four times when it is to be given to a very young infant or one with a weak digestion; after the first two to three weeks dilute with twice the quantity of water; from two to three months increase gradually to equal parts; from four to six months give two parts of milk to one part of water, then three parts of milk to one of water, four to one, and from the eighth to the twelfth month pure milk. The change in strength of the addition should be made when the child ceases to gain in weight, provided the digestion is perfect. He advises the use of pure grape-sugar or lactose, to make a proportion of six per cent. in the diluted milk. Cane-sugar or beet-sugar may be used instead; the latter is cheaper. Lactose, on the whole, seems preferable; it is the natural sugar present in milk, and also has the property of aiding in the digestion of proteids. By splitting up into lactic acid it acts as an intestinal antiseptic.

Wheat-, barley-, or oatmeal-water, or plain water, may be used as diluents, according to the state of the child's digestion.

Biedert estimates that from one hundred and fifty to two hundred cubic centimetres of food are necessary for each kilogramme of body weight during the twenty-four hours. Feed at first every two hours; then rapidly diminish the number of feedings to eight, seven, six, or even five in the twenty-four hours; avoid night feedings if possible. When a child is weakly, it can be fed every two and a half or three hours from four A.M. to ten P.M.,—that is, seven or eight meals a day.

Biedert's Cream Mixture.

Age.	Cream. Litre.	Water. Litre.	Sugar. Grammes.	Milk. Litre.	Casein. Per cent.	Fat. Per cent.	Sugar. Per cent.	Calories in 100 cc.
First month	$\frac{1}{8}$	$\frac{3}{8}$	18	..	0.9	2.5	5	47
Second month..........	$\frac{1}{8}$	$\frac{3}{8}$	18	$\frac{1}{16}$	1.2	2.6	5	49
Third to fourth month..	$\frac{1}{8}$	$\frac{3}{8}$	18	$\frac{1}{8}$	1.4	2.7	5	51
Fourth to fifth month ..	$\frac{1}{8}$	$\frac{3}{8}$	18	$\frac{1}{4}$	1.7	2.9	5	54
Sixth to seventh month	$\frac{1}{8}$	$\frac{3}{8}$	18	$\frac{3}{8}$	2.0	3.0	5	56
Eighth to twelfth month.	$\frac{1}{8}$	$\frac{1}{4}$	12	$\frac{3}{4}$	2.5	2.7	5	56

A cream containing from eight to ten per cent. fat should be used in this mixture. In his latest edition Biedert recommends six per cent. sugar instead of five per cent. Indications for using the cream mixture are given by Biedert as follows: prolonged digestive disturbances which do not yield to simple dilution of cow's milk, constipation alone or alternating with enteritis, and mucous enteritis. A bad result means, of course, that the digestive apparatus cannot handle fat. If fat diarrhœa occurs, we may have to used skimmed milk.

Biedert's Cream Conserve is a paste containing 7.1 per cent. casein, 15.5 per cent. fat, and thirty-five per cent. sugar, sterilized by heat. A large number of formulæ can be constructed by the addition of milk and water to this conserve. For example:

MIXTURE No. 1.

One tablespoonful conserve....	=	1.0 per cent. albumin
Thirteen tablespoonfuls water..		1.7 per cent. fat.
Two tablespoonfuls milk......		3.3 per cent. sugar.

MIXTURE No. 5.

One tablespoonful conserve....	=	1.5 per cent. albumin.
Thirteen tablespoonfuls water..		2.1 per cent. fat.
Six tablespoonfuls milk.......		3.5 per cent. sugar.

Many of the other thickened cream conserves, such as Lahmann's Vegetable Milk, Loeflund's Cream Conserve, and Allenbury's Infant Foods, are compounded on similar lines.

At the 1899 meeting of the Society of German Naturalists and Physicians Biedert stated that we should not use one type of milk for all cases, but a mixture of milk, cream, water, or other diluents which can be altered at will.

HEUBNER [70] thinks that healthy children can be given large amounts of proteids without harm; an excess of proteids is less harmful than an excess of fluids. Basch has shown that casein is well digested by trypsin in the space of from four to five hours without leaving any nuclein remnant. The presence of undigested casein in the diarrhœal stools does not prove that the healthy infant cannot digest casein in proper amount.

Heubner's method, which can also be called the calorimetric, is based on the principle of diluting cow's milk as little as possible; it is intended to furnish a food mixture which will closely resemble mother's milk in the number of calories it contains.

Heubner's Mixture is prepared as follows: one pint of cow's milk is diluted with half a pint of oatmeal- or barley-water, sterilized in the Soxhlet apparatus for fifteen minutes, and quickly cooled and kept cool till ready for use. Instead of the oatmeal-water, two teaspoonfuls of Rademann's or Kufeke's Meal may be added to a pint of water and boiled down to

half a pint (from a half to three-quarters of an hour). Enough lactose should be added to the mixture to make the percentage of sugar equal seven; this should be done in the last five minutes.

One litre of this mixture will represent two per cent. proteids, 2.2 per cent. fat, and 7.2 per cent. sugar, and will be equivalent to five hundred and eighty calories. This mixture is not suited to every case; for children of very low weight, with weak digestive powers, and for sick infants we must use sometimes a weaker mixture,—namely, we must dilute the milk one-half or two-thirds. The child should be fed every three hours.

Feer [53] gives in the subjoined table the amounts of cow's milk, water, and lactose administered in the Heubner-Hoffmann-Soxhlet Mixture at different periods of the infant's life, and compares the figures with the quantities required by the child at the breast. They represent the total quantity in the twenty-four hours.

	Breast-milk. Cc.	Cow's milk. Cc.	Water. Cc.	Lactose. Grammes.
First week	300	50–200	100	12
Second week	550	350	200	24
Third week	600	400	200	24
Fourth week	650	400	250	30
Fifth week	700	450	250	30
Sixth week	750	500	250	30
Seventh to eighth week	800	520	300	37
Ninth to twelfth week	825	550	300	37
Thirteenth to sixteenth week	875	600	300	37
Seventeenth to twentieth week	925	600	350	43
Twenty-first to twenty-fourth week	975	650	350	43

Heubner.[70] In the nourishment of the breast-fed infant the quantitative are greater than the qualitative differences; this without prejudice to the growth of the child. The number

of calories required by children of equal weight and development varies greatly. This has been shown by a series of observations on the children of physicians. Children of equal weight and age would take quantities varying widely, some requiring twice as much as others. Qualitative tests of the milk were not carried out, but it is not likely that they varied sufficiently to account for such differences. The mothers all lived under good hygienic conditions.

Heubner gives the following table of the number of calories consumed by children on different milk mixtures:

	Mother's milk.	Heubner's Two-thirds Mixture.	Biedert's One-third Mixture.
	Calories.	Calories.	Calories.
A child weighing 3300 grammes will take:	328	360	214
A child weighing 4000 grammes will take:	409	450	260
A child weighing 4500 grammes will take:	502	540	318
A child weighing 5400 grammes will take:	496	540	350

Camerer and Söldner find very low fat percentages in mother's milk in the latter months of lactation. Between the third week and the fourth month the average is 3.66 per cent. We can assume an average of 3.5 per cent. without danger of giving too high a figure. In one litre of mother's milk there are from ten to twelve grammes of proteids, yielding from forty-one to forty-nine calories; thirty-five grammes of fat, yielding 325.5 calories; and sixty-five grammes of sugar, yielding 266.5 calories; total, six hundred and twenty calories.

Children of equal age and weight, fed on greatly different amounts of milk (even double the quantity, *vide supra*), will show a like increase in weight. It is evident, then, that different children require a different number of calories per kilogramme of body weight for their growth and nourishment. If this difference exists in human milk, we should expect to find that the same holds good in the case of artificially fed infants. *Some* will thrive on low proteids and high fat per-

centages; or, *vice versa,* on high proteids and low fat; or on a mixture rich in sugar, such as condensed milk preparations; or on preparations containing starches; or even on peptone and egg albumin, granting the necessary cleanliness in the preservation and the preparation. These kinds of foods are useful in tiding the infant over to a diet of cow's milk, slightly diluted, or to mixed feeding. They do not all possess the same food value. Some make more demands on the infant's digestion than do others; at the same time, infants seem to be able to dispose of very differently constituted food-stuffs. We should not depend on the infant's powers of digestion, but should as far as possible take the child's natural food (breast-milk) as an example.

Gaertner's Milk has an average value of six hundred and twelve calories per litre, and *Backhaus Milk* six hundred and thirty calories to one litre.

	Proteids. Per cent.	Fat. Per cent.	Sugar. Per cent.
Woman's milk........................	1–1.2	3.5 –4	6.5 –7
Backhaus Milk	1.75	3.25	6.75
Gaertner's Milk......................	1.67	3.2	6.00
Heubner's Mixture (two-thirds strength).	2.27	2.3	7.00

Heubner is inclined to think that scurvy may follow the prolonged use of these prepared infant foods. While sterilization may also carry dangers with it in this respect, it is unfortunately necessary.

The value of the artificial cream foods is at present established more on a theoretical than a practical basis. The value of any child's food depends largely on the cleanliness observed in its handling and preparation, its administration in correct quantities (without other food), and the general hygiene surrounding the child's person.

Bendix [10] thinks that it is not so much the question how to render the casein digestible as how to reduce it to the proper

proportion by dilution with water or barley-water. He agrees with Heubner that one should give the actual amounts of the food constituents which are necessary without laying too much stress on the relative dilution.

Seifert,[59] in the last edition of Gerhardt's text-book, advises that the Heubner-Hoffmann Mixture should be used, sterilized in the Soxhlet apparatus. The latter is not perfect, but it is at present the best means we have for rendering the milk sterile and so adapted to the infant's use.

Henoch,[71] in the last edition of his "Lectures on Children's Diseases," recommends for the first two or three months one part of milk to two or three parts of water; from four to six months one part of milk to two of water; from six to nine months equal parts, or two parts of milk to one of water: after ten months he gives whole milk. Each case should be fed according to its particular needs.

Baginsky [6] finds that two essential difficulties exist in the problem of infant feeding: first, the qualitative and quantitative differences in the chemical composition of woman's milk and cow's milk; second, the presence of bacteria and their toxins. When the dirt and bacterial content of cow's milk are diminished, the results of feeding children with it are so satisfactory that in the case of healthy infants elaborate methods of altering its composition become of little value or even superfluous. With regard to the first point, we must reduce the proteid percentage and add sugar. The numerous quantitative variations in the proteid content of mother's milk prevent the establishment of an absolute standard for the degree of dilution; neither can the total quantity of food to be administered daily be rigidly determined. As the amount of milk which a child at the breast will take varies within considerable limits in each individual case, so also in the case of cow's milk it is impossible, in the absence of a more definite basis for computation, to establish any absolutely fixed or definite standard for the total quantity to be given. Biedert has calculated that

when cow's milk is diluted so that its casein content amounts to one per cent., the infant requires for each kilogramme of his body weight two hundred cubic centimetres of milk. This rule may hold good for many cases, but the degree of dilution and the total daily quantity of food must be determined finally by the digestive capacity in each individual case. The latter is best estimated by the use of the scales. Some children certainly tolerate more concentrated nourishment and more liberal quantities of food than others. In fact, many authors, especially the French (Budin, Variot, and others), advise to give whole milk from the beginning. On the other hand, some infants digest casein with difficulty, while in other cases richness in fat content is the stumbling-block. Only the most careful observation of the child's general condition and inspection of the fæces will save the physician from mistakes in treatment. In general one can begin with a dilution of three parts of water and one part of milk, gradually diminishing the amount of water until, towards the end of the third month, a mixture of equal parts of milk and water is reached. Instead of water, dilute oatmeal-water may be used, or solutions of one of the infant foods. The addition of milk-sugar must not be forgotten. Whole milk is often well tolerated at the end of the ninth month. In view of what has been said, the following table of quantities at each feeding is to be considered merely a general guide for the practitioner; it is not intended to take the place of careful personal observation and study of the needs of each individual case (size, weight, power of digestion, etc.). Baginsky has found this method of dilution satisfactory in a practice covering many years. He sees no reason to modify it in any essential respect, notwithstanding the fact that the recent metabolism work of Heubner and Rubner seems to controvert its principles. Each child has its individual powers of digestion. It is well to begin with the more dilute mixtures and to advance to those more concentrated, guided always by the results of careful clinical observation.

Baginsky's Table of Feeding.

Class.	Age.	Total quantity of milk.	Mixture.	Feedings.	Quantity.
A.	Over one year	1500 cubic centimetres	50 grammes sugar	6	250 cubic centimetres
B.	Nine to twelve months	1125 cubic centimetres	1125 grammes milk 375 grammes water 50 grammes sugar	6	250 cubic centimetres
C.	Five to nine months	750 cubic centimetres	750 grammes milk 375 grammes water 50 grammes sugar	6	Three of 200 cubic centimetres and three of 180 cubic centimetres
D.	Four to five months	500 cubic centimetres	500 grammes milk 500 grammes water 40 grammes sugar	6	Three of 180 cubic centimetres and three of 150 cubic centimetres
E.	Two to four months	350 cubic centimetres	350 grammes milk 700 grammes water 36 grammes sugar	7	150 cubic centimetres
F.	Birth to two months	200 cubic centimetres	200 grammes milk 600 grammes water 30 grammes sugar	8	100 cubic centimetres

The use of barley-water and similar weak starchy preparations has long been recommended and is of undoubted value in rendering milk more digestible by lessening the size of the clots. Rudisch's proposal to effect the same by the addition of dilute hydrochloric acid has not found favor. Monti's Whey Mixture, Voltmer's Mother's Milk, and Backhaus Milk are defective in that they show a departure from the normal,—a deficiency in either fat, albumin, or sugar which is hard to remedy. Doubtless they will all give good results in a large number of cases, but as certainly not in all cases, and faulty nutrition will result unless the greatest care is exercised. It is a mistake to use calories as a basis for feeding infants; reckonings of this kind are of value in estimating the total food requirements of the organism, but one should never, on this theoretical basis, attempt to substitute fat for proteids or sugar for fat.

The infant's body requires, even more than the adult's, a definite quantity of food-stuffs for the period of growth, and it will more easily select and assimilate the same from a mixture of apparently faulty qualitative composition than it will handle a food which theoretically and quantitatively is correctly put together to represent a certain value in calories. If the organism needs fat, it will not thrive if sugar is offered in its place; the same is true of albumin. Herein lies the great danger of the modern habit of considering this question from the chemical stand-point.

Baginsky does not recommend the use of Rieth's Albumose Milk, Lahmann's Vegetable Milk, Gaertner's Fat Milk, or Loeflund's Cream Conserve. All conserves are distinctly inferior to fresh cow's milk, and their use is apt to be followed by severe anæmia and scurvy.

MONTI.[99] When cow's milk is to be used as an infant food, the following principles must be kept in mind: (1) The acidity must be diminished, as it is three times that of mother's

milk.* (2) The casein must be diminished and its tendency to clot in large lumps altered; the lesser amount of soluble albuminoids in cow's milk must be made up and their relative proportion to the casein present improved. (3) The lesser amount of fat and the unfavorable proportion of fat to casein must be considered. (4) The bacteria must be rendered harmless. (5) The lesser amount of sugar must be compensated for. (6) The salts must be reduced and maternal conditions imitated as closely as possible. Monti prefers mixed feeding to the exclusive use of artificial food, and, even if the mother's milk is defective, he advises to wait until after the sixth week before giving cow's milk, since the latter will be better tolerated after that time.

Monti then criticises the methods of Heubner, Hoffmann, and Soxhlet. The *Heubner-Hoffmann Mixture* is presented in a very concentrated form and will not be as well assimilated as mother's milk; it contains too little soluble albumin, especially for the first months of life, and the percentage of fat is too low. Soxhlet has endeavored to supply the deficiency in fat by the addition of lactose. The amount of lactose needed is based on Rubner's statement that one hundred parts of fat are isodynamic with two hundred and forty-three parts of sugar; then 1.32 parts of fat will equal 3.19 parts of milk-sugar. Cow's milk is mixed with one-half its amount of 12.3 per cent. lactose solution; this gives the following percentages: water 85.3, proteids 2.37, fat 2.46, fat represented by lactose 1.32 (3.78 fat), lactose as equivalent for absent fat 3.19, natural lactose content 3.25, lactose added to supply deficiency 2.96; total lactose content 9.40. In Monti's opinion, Soxhlet's Mixture contains too much lactose. This is apt to cause diarrhœa, and is therefore not a good substitute for fat.

* Wolf and Friedjung, in Monti's clinic, found that the acidity of freshly milked breast-milk was only 0.1, tested with a decinormal soda solution; whereas the acidity of raw cow's milk, even when fresh, amounted to 1.1 and over. (Reported at Paris Congress.)

Marfan's Mixture contains too much lactose, excessive proteids, and is too concentrated, like the Heubner-Hoffmann Mixture. Monti therefore condemns it. The same criticism applies to Siebert's method.

Monti considers that Biedert, in his *Cream Mixtures,* gives quantities which are in excess of the actual capacity of the stomach, that he increases the proportion of proteids too rapidly, and that he gives a slight excess of proteids and fat during the first weeks of life. Since fresh cream varies in its composition, and since its digestibility is altered by sterilization, its use should be restricted to those cases in which no other form of milk mixture will be tolerated.

Biedert's Cream Conserve, if well prepared and completely sterile, may be useful for a certain class of cases, but is not adapted to take the place of fresh milk; Heubner expresses the same opinion.

Vigier's Humanized Milk (1893) is prepared by taking a definite quantity of milk and dividing it into two equal parts. The first half is left untouched; the second half stands until the cream separates completely, when the cream is removed. The skimmed milk is coagulated and the serum obtained is added to the first half, as is the separated cream. This is sterilized. Its composition is as follows, according to Gautrelet: casein 2.36 per cent., fat 3.75 per cent., lactose 4.10 per cent., carbohydrates 0.81 per cent., salts 0.7 per cent.

Monti's Whey-Milk Mixture is prepared in the following manner. The whey is separated from one litre of good cow's milk, rich in fat, by heating the same to 35° C. and adding one gramme of French lab-ferment dissolved in forty cubic centimetres of distilled water. The latter must be prepared freshly each time. Allow the mixture to stand until it becomes jelly-like, which will require from twenty-five to thirty minutes; then apply heat again up to 68° C.; this will destroy the lab-ferment. Let the mixture stand till cool and filter through a silk cloth. Whey prepared in this manner

will be alkaline, of a specific gravity of from 1020 to 1027, and will contain: casein 0.03 per cent., soluble albumin from 0.80 to one per cent., fat one per cent., sugar from 4.5 to five per cent., salts 0.7 per cent.

For the first five months of life a mixture of equal parts of milk and whey is suitable; to older infants, if not improving as they should, two parts of milk to one of whey should be given. After cooling, the mixture is put in sterile bottles and pasteurized in the Soxhlet apparatus for from ten to fifteen minutes at from 68° to 70° C.; it is then cooled to 8° C. and kept at this temperature until used.

The composition of the mixtures will be as follows:

	Casein. Per cent.	Soluble albumin. Per cent.	Fat. Per cent.	Sugar. Per cent.	Salts. Per cent.
Mixture No. I..........	1.22	0.8–1.0	2.33	4.5–5	0.7
Mixture No. II.........	1.61	0.8–1.0	3.11	4.5–5	0.7

Monti considers that these mixtures correspond very closely to mother's milk in their proteid percentages, while the content of fat and sugar is lower than in mother's milk. He believes that young infants thrive better on low fat and sugar percentages in artificial feeding than when these ingredients are present in larger quantity. Wolff and Paccini have obtained good results with the Monti Mixture; the latter used two parts of whey to one of milk rich in fat, and so obtained a mixture containing casein one per cent., fat three per cent., sugar five per cent., and rather more soluble albumin than in the Monti Mixture.

Schlossmann has emphasized the value of a mixture of whey and cow's milk from the theoretical stand-point. He thinks that the addition of soluble albumin to cow's milk has a decided influence on the form of casein precipitation. To demonstrate this, he took a cream containing seven and a half per cent. fat and 1.06 per cent. casein, and diluted one-half

the quantity with equal parts of water and the other half with an equal part of one per cent. serum-albumin solution. The latter mixture resembles mother's milk in its chemical composition, containing 3.75 per cent. fat and 0.8 per cent. casein with 0.5 per cent. albumin. The first half of the mixture contains just as much fat and casein, but practically no albumin. These mixtures were both tested with artificial gastric juice in an incubator. The first half showed the formation of large, firm, uneven clots; the second half showed precipitated casein in a finely divided condition, covering the bottom of the tube as a finely granular deposit of soft and even consistency.

Use of Diluents.—In Monti's opinion, there is no advantage to be gained from the use of barley-water, oatmeal-water, etc., that cannot be equally well obtained with plain water. The casein clots are just as coarse in either case, and digestion is not rendered any easier. Moreover, the cereals are apt to cause meteorism and dyspeptic symptoms, especially in young infants, and have no especial nutritive value.

At the Paris Congress of 1900 Monti recommended the use of sodium carbonate to counteract the acidity of artificial milk mixtures. The special advantage gained by the use of whey-milk mixtures is that we thereby increase the proportion of soluble albumin and render coagulation by lab-ferment more nearly like that which occurs in the stomach of the breast-fed infant. The fat content of cow's milk is reduced by this degree of dilution, and to make up the deficiency by the addition of cream cannot be recommended, since the milk will then contain relatively too many fatty acids. The infant does not digest and assimilate cream readily; moreover, the fat emulsion is affected by centrifugation, so that large drops rise to the surface. Two per cent. is a quite high enough fat content, and will suffice for the infant's needs if the correct proportion of proteids and sugar is given. The sugar content is best regulated by the addition of pure whey.

Monti disapproves of sterilization on account of the great changes it causes in milk; he prefers to heat for ten minutes at from 60° to 70° C., and then to cool to 6° C. until used. He advises to allow three-hour intervals between feedings, to suit the amount to the capacity of the stomach, and to give proportionately less than the child at the breast would take, since cow's milk is digested with more difficulty.

Lahmann's Vegetable Milk, according to Stutzer's analyses, contains: fat twenty-five per cent., nitrogenous substances, principally plant-albumin, ten per cent., sugar and other non-nitrogenous substances 38.5 per cent., mineral materials 1.5 per cent., water twenty-five per cent. It is asserted that the presence of vegetable albumin in this preparation renders the digestion of the proteids more easy by furnishing conditions approximating precipitation of the casein of mother's milk by lab and peptic ferments. Since this preparation contains elements which are not found in mother's milk, it cannot be considered a normal food.

Backhaus Milk is prepared as follows, according to the latest modifications of its originator.[16] Good fresh milk is separated by centrifugation into cream and skimmed milk; a mixture of trypsin, lab-ferment, and a one-half per cent. solution of sodium carbonate is then heated to a temperature of 40° C. and added to the skimmed milk. The casein is first coagulated by the lab, then the trypsin in the presence of the alkali redissolves and peptonizes part of the casein, so that at the end of half an hour 1.25 per cent. of soluble proteids is present. By heating to 80° C. the action of the enzyme is destroyed. The separated casein is then removed by straining or by centrifugation, and cream is added of sufficient concentration to give 3.5 per cent. of fat and 0.5 per cent. of casein; finally one per cent. of lactose is added, and the mixture is put in separate bottles and sterilized.

This preparation is practically a peptonized milk, and time and care are requisite for its manufacture. Biedert and Heub-

ner agree that the natural properties of milk are altered by the artificial modifications which this process requires.

Voltmer's Mother's Milk.—This is essentially a peptonized milk which has received additions of fat and sugar. It may be made fresh or as a conserve; three mixtures of different strengths are prepared. The composition of the conserve is liable to vary. Heubner considers Voltmer's Milk valuable as a temporary expedient in weakly infants, especially for the first weeks of life. Drews [45] thinks that it is adapted to general use, both for sick and healthy children, and that children fed on it are no more liable to gastro-intestinal disturbances than those at the breast. He cites a large number of cases.

Loeflund's Peptonized Child's Milk.—This food is similar to the last-named preparation, and can be used temporarily in like manner. In Monti's opinion, it has no advantages over milk which is peptonized at home.

Loeflund's Cream Conserve differs from Biedert's in containing maltose instead of cane-sugar. Its analysis reads: sugar fifty per cent., fat twenty-three per cent., proteids five per cent., ash 1.8 per cent., water 20.2 per cent. In Biedert's estimation, the presence of maltose is useful.

Gaertner's Milk [7] is made by dividing into two equal parts in the separator a bulk of milk diluted equally with water. The mixture will then contain nearly all the fat in an emulsified state, and one-half the quantity of proteids, sugar, and salts contained in the original milk. Apart from this, Biedert sees no particular advantage in Gaertner's Milk over ordinary cream mixtures. Its specific gravity ranges from 1020 to 1030, and an analysis of its contents gives the following average: casein 1.76 per cent., fat three per cent., sugar 2.4 per cent. It is not as sweet as whole milk, but the taste is not unpleasant; it clots in smaller flakes than cow's milk.

Marfan has observed that large fat-droplets collect on the surface of Gaertner's Milk, after it has stood for some time,

and form a yellow skim. After several hours the emulsion is not readily re-formed.

Monti thinks that the composition of Gaertner's Milk is inconstant; the reports as to its use are very contradictory. Monti asserts that the centrifugation disturbs the emulsion of the fat and causes a conglomeration of the fat-globules. The influence of the fat-corpuscles in favoring the finer coagulation of the casein is thus impaired and absorption is hindered. Microscopical examination confirms these statements. In Monti's experience, the amount of fæces is apt to be large when infants are fed on Gaertner's Milk. Gaertner's Milk may be used temporarily to meet definite indications, but it must not be considered an absolute substitute for mother's milk.

Thiemich and Papiewsky,[144] from the observation of thirty cases, conclude that Gaertner's Milk can be used when there are digestive disturbances, but possesses no advantages over dilutions of cow's milk. Czerny thinks that Gaertner's Milk and Backhaus Milk are not efficient substitutes for mother's milk when the child is sick. Fat milk is useful in constipation, but in many cases it is not well borne. Escherich is a strong advocate of the use of Gaertner's Milk; many of the good results which he obtained were in the case of healthy infants who had just been weaned or who were getting mixed feeding.

John Lovett Morse, of Boston, in "A Consideration of Professor Gaertner's Mother's Milk," [218] states that its manufacture was first begun in this country in 1897. His conclusions in regard to it are as follows. It contains only the constituents of cow's milk, and they are present in approximately the same proportions as in human milk; but they are not constant, are unknown to the consumer, and are insusceptible of modification. It is not a "fresh" food, and costs as much or more than modified milk which is freshly prepared and whose proportions can be varied.

Rieth's Albumose Milk is a preparation of soluble albumin, obtained by heating egg albumin to over 130° C. Cream and

lactose are added in sufficient quantity to make a product similar to mother's milk. Monti thinks that it is not fit to be a permanent food, but agrees with Hauser and Baginsky that it may give good results in isolated cases.

An objection which applies to all of these products is their cost. Baginsky deserves credit for having drawn attention to the fact that these foods do not give us the same results as fresh milk; marked anæmia and scorbutic affections frequently follow their prolonged use, notwithstanding that the children become fat. At the time when Liebig's soup and condensed and conserved milk preparations were in general use, Monti often noticed that children fed on fresh cow's milk were not subject to anæmic and hemorrhagic disorders. (In general it may be said of all these preparations that none of them justifies the claims put forward by their originators; their use must necessarily be limited, and they cannot take the place of properly modified cow's milk.—EDITORS.)

Steffen's Veal Broth.—Steffen has lately recommended a mixture of cow's milk, veal broth, and cream, prepared as follows. One hundred and forty grammes of veal are added to half a litre of water and cooked for from a half to three-quarters of an hour, boiling water being added from time to time to keep up the original quantity. Salt must not be added. Veal broth and milk are mixed in equal parts, and to each one hundred cubic centimetres of the mixture five cubic centimetres of cream and 3.8 grammes of lactose are added; it is then sterilized in the Soxhlet apparatus. This mixture contains: casein 1.8 per cent., fat 3.1 per cent., sugar 6.2 per cent., salts 0.45 per cent.

For the new-born one part of milk and three parts of broth are to be used; this will contain from 0.25 to 0.35 per cent. of salts, which is greater than the proportion in mother's milk. For the later periods of nursing two parts of milk and one part of broth should be given; if there is constipation, give less milk and more cream.

This preparation has a pleasant taste and smell and an amphoteric reaction. The potassium salts in veal broth increase the alkalinity and facilitate the digestion of the casein. Good results were obtained by Steffen in his own experience of ten years; his father used the veal broth for twenty years with uniform success. Rickets was not observed. Both sick and healthy children took the mixture well.

GREGOR.[65] *Malt Soup.*—Fresh milk is obtained directly from the farm and cooled as usual. It must not be boiled. To two-thirds of a litre of water heated to from 50° to 60° C. one hundred cubic centimetres of Loeflund's malt extract and ten cubic centimetres of an eleven per cent. solution of potassium carbonate are added. At the same time fifty cubic centimetres of wheat flour are added to one-third of a litre of milk and stirred till an even consistence is reached. This is passed through a fine sieve, and then the two are mixed together and brought to a boil, with constant stirring.

If one litre is to be given for the daily portion, heating to the boiling point requires from six to ten minutes. If from eight to ten litres are to be prepared, twenty to thirty minutes are required. To avoid overheating, remove the heat when a temperature of 94° C. is reached for the smaller and 98° C. for the larger quantity. The mixture as prepared is thin and has a good spicy taste of malt. In hot weather it should be kept cool and in sterile bottles. Sterilization is apt to cause separation of the fat, which impairs the nutritive value of the soup. For infants from one and a half to three months of age Gregor uses less malt extract and less flour; and for infants from nine to fifteen months of age, half milk and half maltose solution (less malt is used to make the solution). Good results were obtained with this preparation in over seventy-five per cent. of the cases which presented themselves for treatment (including atrophic cases and severe gastro-intestinal diseases), seventy-three in all. Gregor recommends the use of malt soup in diluted form to infants under three months, provided that

its administration can be closely supervised. It gives good results in gastro-intestinal affections, malnutrition, and rickets, and may be employed when the child is weaned or for mixed feeding. Keller also uses malt soup with good results.

At the seventy-third meeting of the Society of German Naturalists and Physicians SALGE presented a paper on the use of *buttermilk* for infant feeding.[142] He considers it adapted for the child's diet when convalescent from acute digestive disturbances and in atrophic cases. It may be added to malt soup or as a supplement to breast-milk. It must be fresh and clean and carefully prepared from sour cream. The average formula will be: from 2.5 to 2.7 per cent. proteids, 0.5 to one per cent. fat, and 2.8 to three per cent. sugar. According to Rubner, one litre will furnish seven hundred and fourteen calories.

One hundred and nineteen cases were fed on it at the Charité (Berlin); of these, eighty-five gave favorable results. The fæces contained many lactic acid bacilli and were of firm consistence; in some cases there was constipation. To each litre of buttermilk fifteen grammes of meal and sixty grammes of cane-sugar were added, and it was then heated slowly to boiling. Investigations as to the absorption of proteids and fat, which are not as yet completed, show that the greater portion of them is absorbed.

SCHLOSSMANN reported at the same meeting that he had fed one hundred and fifty infants on buttermilk with good results. If the gain in weight was not satisfactory, he added cream.

FILATOW,[58] of St. Petersburg, advises to give the new-born infant milk diluted three times with a solution of oatmeal-, rice-, or barley-water, adding two or three teaspoonfuls of sugar to each half-pint. From one to three months give one part of milk to two of water, from three to four months equal parts, from four to six months two parts of milk to one part of water, and after six months pure milk. This scheme can, of course, be varied to suit the infant's development and its powers of digestion. A child below five months of age can take

at one time as many ounces as its age plus one,—*e.g.*, at three months four ounces, at five months six ounces, etc. From six to twelve months give six ounces at a feeding. Up to the second month feed every two hours in the day and twice at night; from two to four months feed every three hours in the day and once at night,—seven meals in all. After this feed six times in the twenty-four hours. No starchy food should be given before the fourth month. Cleanliness in obtaining and handling the milk is essential. In case the child cannot take cow's milk, try Biedert's Cream Mixture or Gaertner's Milk.

SCHLESINGER,[139, 227] of Breslau, recommends the use of pure undiluted cow's milk for infant feeding; this may be sterilized if necessary. The calorie value of woman's milk is almost identical with that of undiluted cow's milk. The more cow's milk is diluted the lower will its food value fall and the more insufficient will it become for the infant's needs. Dilution with water does not render the casein more digestible; the fact is, by diluting milk from two to three times we simply flood the system with water, for the child has to take a much larger quantity of food to get the necessary quotient for its proper growth. Such a flooding of the system entails greater work on the part of the organs of digestion and assimilation, and often leads to marked dyspeptic disturbances, gastric dilatation, and finally atrophy. Schlesinger therefore advises to give small quantities of whole milk even during the first month of life.

CZERNY [34] also believes that we injure the child by giving too weak dilutions, and that some of the normal salts in the economy will be washed out by an excessive administration of water. The danger of giving too much proteids is still greater, however; Czerny therefore agrees with Heubner that we should give concentrated mixtures containing a moderate amount of proteids. The intervals between feedings should be long,—at least four hours.

KELLER [84] considers that in the normal artificially fed in-

fant the stomach contents are evacuated about three hours after taking food; free hydrochloric acid is present only two hours later. It has been observed that constant burdening of the stomach with food diminishes the secretion of hydrochloric acid and the gastric motility. In sick children we often find food remnants in the absence of hydrochloric acid as long as four or five hours after a meal. An interval long enough to allow the stomach to empty itself completely seems to be necessary for the re-establishment of the secretory and motor functions of the stomach.

The addition of maltose to milk diminishes the destruction of the albuminoid substances in the economy, and permits the maintenance of nitrogenous equilibrium without the necessity for excessive proteids in the diet. It is therefore the best form in which to administer carbohydrates to infants.

SCHMID-MONNARD,[127] of Halle, does not believe in the use of food which has been subjected to prolonged heat; fresh milk must be employed for the purposes of infant feeding, to which cream, water, and sugar are to be added. There are marked variations in the quantity of food required by artificially fed as well as breast-fed babies; the daily number of calories required remains, however, about the same,—namely, one hundred and thirty-three calories per kilogramme of body weight for artificially fed and ninety-nine calories per kilogramme for breast-fed infants. The number of calories needed during the first six months varies from one hundred and seventeen to one hundred and thirty-nine per day for each kilogramme of body weight in bottle-fed babies; the gain in weight, which diminishes with the age of the child, amounts to thirty-five grammes daily during the first month, 16.3 grammes during the third month, and 8.1 grammes during the sixth month. There are great variations in the weight increase, although the average gain is essentially the same as in breast-fed babies. Notwithstanding the greater number of calories supplied, the

body weight of bottle-fed infants does not increase proportionally as fast as that of sucklings.

The proper food for strong children up to six months of age is milk diluted one-half or two-thirds, with sugar added; for weaker children milk diluted one-third, with cream and sugar added. Schmid-Monnard thinks that infants of low weight and delicate constitution assimilate proteids better than stronger infants, in whom the casein passes more or less undigested through the intestinal tract. Even in the most dilute mixtures there are enough proteids, but not enough fat and sugar to supply the needs of the body. Whereas the nursing child takes in its first year three and a half kilogrammes of proteids, twelve kilogrammes of fat, and twenty kilogrammes of sugar, artificially fed babies get in their first six months five and a half kilogrammes of proteids, six and two-thirds kilogrammes of fat, and ten and a half kilogrammes of sugar, —enough proteids, but scarcely enough fat and sugar.

Marfan [105] concludes, on the basis of his clinical experience, that healthy infants can, as a rule, digest pure sterilized cow's milk after the fourth to the fifth month; before that time even the purest milk should not be given undiluted. He has found that healthy infants under four or five months, who are fed on pure cow's milk, fall into one of three classes:

I. The first and smallest class show signs of chronic gastro-intestinal inflammation with general atrophy and cachexia.

II. The second class show no anomalies, especially those infants who have had the breast for the first few weeks.

III. The third and largest class, which includes those in especial who have received nothing but pure cow's milk since birth, are apparently well, but on examination we find them suffering from constipation; the stools are pasty and putty-colored, and constipation alternates with diarrhœa; vomiting is frequent. It is probable that this dyspepsia is due to a mild form of gastro-enteritis (pure cow's milk dyspepsia). Variot advises that cow's milk should be diluted three or four times

during the first weeks of life; a little sugar should be added. Gauchas believes that cow's milk should be diluted during the first four or five months of the child's existence.

The method which Marfan has followed during recent years consists in the use of milk diluted with boiled water to which enough sugar is added to make a ten per cent. solution. For the first five or six days the mixture should be half milk and half sugar solution; from this time up to four or five months the mixture should be two-thirds milk and one-third sugar solution; after this time Marfan tries to give whole milk, with enough sugar added to bring the sugar percentage up to six. If digestive disturbances arise, he dilutes the milk three or four times with sugar-water. The milk should be sterilized at 100° C. in small bottles on the "bain-marie," after mixing with sugar-water.

Marfan does not consider that it is necessary to reduce the casein to the proportions found in mother's milk, the only object of dilution being to render the casein more digestible. By adding ten per cent. sugar solution we can to a certain extent supply the deficit in fat. His mixture of two parts of milk and one part of ten per cent. sugar solution contains 2.2 per cent. casein, seven per cent. sugar, and 2.4 per cent. fat, with 0.4 per cent. salts. By giving a mixture of this strength we avoid overcharging the stomach with too great a quantity of diluted milk. It is important to use a milk which is rich in fat (from 3.8 to four per cent.). Marfan doubts the advisability of adding salt, sodium bicarbonate, or lime-water. Salt is only useful in certain cases of indigestion, to combat lientery, anorexia, and constipation. Milk should not be alkalized before sterilization, and Marfan considers it superfluous except in certain cases of gastric disturbance. His only objection to this method is that the gain in weight is slightly less than in the case of breast-fed infants.

Centrifugation modifies the fat of milk so as to render it difficult of digestion. This explains its failure in cases of

digestive disturbances. Marfan advises that the feedings should always be three hours apart to allow of perfect digestion.

COMBY [229] advises that milk should be diluted in the following manner:

First month .....One-half milk and one-half water.
Second month ...Two-thirds milk and one-third water.
Third month.....Three-quarters milk and one-quarter water.
Fourth month ...Pure milk.

To each one hundred and fifty cubic centimetres of the mixture he adds 4.5 cubic centimetres of sugar. Ordinary sugar or lactose may be used. Water is the best diluent. The mixture should not be too dilute, for in that case the child is likely to take too great a quantity in its efforts to get the amount of nourishment required. Of the alkaline diluents lime-water is the best. Comby believes in mixed feeding if the breast-milk is deficient. At six months the breast-milk almost always has to be supplemented. Panada may be used for weaning; it is made by thoroughly soaking toasted bread or well-cooked biscuit in water, adding butter and salt, and then boiling. It may be thickened with egg. Racahout, salep, and *phosphatine salières* (a mixture of rice, tapioca, potato, and arrowroot in equal parts plus cocoa, sugar, and phosphate of lime; of the latter ingredient 0.20 gramme to each five cubic centimetres of gruel) may be used to thicken milk, broths, and gruels, and are well liked by children. Arrowroot is poor in albuminous substances; it should not be employed early, as indigestion, anæmia, scurvy, etc., result. These preparations are to be used in weaning, always with fresh milk.

BUDIN [23] advises the use of pure cow's milk, sterilized at 100° C., kept in separate bottles, and used within twenty-four hours. Occasionally it is necessary to dilute milk with water for infants under two months; or one can try Vigier's Hu-

manized Milk, Backhaus Milk, or Gaertner's Milk. Variot also recommends the employment of sterilized whole milk.

Boissard[21] uses humanized milk in which the casein percentage is reduced to 1.7 instead of 3.6; this is accomplished by the same method which Gaertner employs in preparing *Mother's Milk*. The milk should be heated to 38° C. and thoroughly mixed by shaking before it is used. The author thinks that pasteurization at home would give more satisfactory results than sterilization, since the former does not alter the taste or composition of the milk.

Jacobi.[76] For the purposes of nutrition nature allows great latitude, since the mother's milk constantly changes from one minute to another, from morning till night, depending on her diet, state of health, menstruation, and stage of lactation,—and still the baby thrives! Thus there is no sameness in human milk, and for that reason no possibility of arranging a perfect and uniform substitute for every kind of it.

The caseins of mother's milk and cow's milk differ both chemically and physiologically. These differences have been studied extensively since Hammarsten first wrote thirty years ago, but to this moment it is not clear whether the albuminoid which is found besides casein is coördinate to it or derived from it. There are some modern observations which seem to prove conclusively that the caseins of different animals cannot be identical any more than are their blood-cells. Wassermann and A. Schütze found that by injecting different animals daily with sterilized cow's milk for a fortnight, their blood-serum acquired the property of coagulating the proteids of cow's milk, but not those of another animal. Similarly, other milks exercised a specific coagulating effect upon their own proteids.

There need be no better proofs of the differences between the caseins of different milks; every animal has its own specific milk adapted to the wants of its own offspring, and the belief that one milk can be substituted for another is a mistake.

In regard to various methods of feeding, Jacobi asks whether it is true that iron-clad rules as to the composition of a substitute are to the point or justified. In his opinion, only one great progress has been made in infant feeding these dozens of years,—namely, the more or less universal introduction of the practice of heating cow's milk and all other substances employed in infant feeding.

In Jacobi's experience with Laboratory Milk, many infants thrive on it for a certain time, for the mixture is sterilized in single feeding-bottles holding prescribed quantities, but very many become more or less rachitic. He has frequently seen mild forms of craniotabes which required the addition of animal food, phosphorus, etc.

There can be no doubt that the end aimed at by Rotch is partly obtained by securing a reliable and approximately fresh milk, and by sterilizing it in small portions. In that he has performed, with Coit and others, most valuable educational and missionary work.

The dilutions Jacobi employs vary from four to six parts of diluent to one part of milk for the new-born, down to equal parts at six months. In general he believes that the proportion of casein should not exceed one per cent. during the early months.

Jacobi prefers cane-sugar to lactose in the preparation of his mixtures, since it is not so easily transformed into lactic and other acids. The identity of the lactose in mother's milk and cow's milk has not been proved, and the lactose of the market is quite often impure. That alone makes it desirable or advisable to substitute cane-sugar, if this affords the same advantages.

After eight-tenths of one per cent. of the lactose contained in whole milk is changed in the stomach into lactic acid, its production ceases. Ordinarily this limit is reached when about one-fourth of the milk-sugar has been so converted. But if at that time lactic acid be neutralized by an alkali, more

milk-sugar is changed into lactic acid. Therefore it appears that in every preparation of cow's milk selected for the use of the infant there is enough milk-sugar to supply the needs of the digestive processes.

Finally, he adds, the antifermentative action of lactic acid displayed during the putrefaction of albuminoids is shared by other sugars and by starch, and Miura has proved that the small intestines of the fœtus and new-born contain an inverting ferment which renders possible the absorption of cane-sugar. To repeat, a milk mixture which contains twenty-five per cent. of milk will furnish enough milk-sugar for the purposes of lactic acid production and of digestion.

The proportion of fat in an infant's diet should never exceed that found in mother's milk. According to Heubner, 5.9 per cent. (in the breast-fed infant), 5.3 per cent. (in the infant fed on cow's milk), and fifteen per cent. (in infants with weak digestion) of the fat introduced in the food is expelled undigested. If so much is expelled unchanged, Jacobi does not consider that the addition of cream to the milk mixture is quite a *sine qua non.* "In the face of these data, cow's milk fat is added to infant food equally in winter and in summer, while the Esquimaux of the cold climate have told us long ago that it is they that require fat, and the ancient Hebrews of the torrid zone that it should be prohibited in broiling climates or seasons. Nor has the frequency of (Biedert's) fat diarrhœa, which has been noticed even in infants nursed by their own mothers, been a warning." Moreover, the fat of cow's milk differs from that of mother's milk. The latter has more oleic acid and less volatile acids than cow's milk. Mother's milk contains its fat in finer emulsion and has from two to four times as many fat-globules as are found in an equally fat cow's milk (Schlossmann). It is reasonable to assume that such fine fat-globules may be absorbed directly through the epithelia of the intestinal villi. The fat of cow's milk, before it is used, undergoes changes: when raised by

the gravity process, it is apt to acidulate; when sterilized and centrifugated, it is changed chemically and physically; when frozen, it separates from the milk and does not mix again. All these facts have led Jacobi to reduce rather than to increase the fat of cow's milk used for infant feeding.

Jacobi is a firm believer in dilution, and has found that "there is not a more frequent cause of dyspepsia, except excessive summer heat and senseless amounts of pasty amylaceous foods, than undiluted cow's milk in the well and the sick infant." The objections made on the ground that large amounts of food may cause gastric dilatation, he believes, are theoretical. The rapid action of the almost vertical stomach and the rapid absorption from it and from the intestine of fluids containing salts and sugar render gastric dilatation "very improbable—probably impossible." Water does not act like bulky indigestible food, and diabetics may drink daily from five to ten litres of it for years without dilatation of the stomach from that cause. Furthermore, a great quantity of water is needed to assist in pepsin digestion. In artificial digestion, albumin often remains unchanged until large quantities of acidulated water are supplied. Peptones require water to facilitate their solution and absorption; moreover, it is certainly true that large amounts of water passing through the kidneys reduce the danger of uric acid infarcts, the results of which are gravel, renal calculus, and nephritis.

Where plain water is to be used, it will generally give greater satisfaction if it has previously been boiled, in the case of very young infants, even if there be no apparent urgency for it.

Dilutions with plain water may seem to be harmless; in many instances children thrive on them. More, however, only appear to do well, for increasing weight and obesity are not synonymous with health and strength. A better way to dilute cow's milk, and at the same time to render its casein less liable to coagulate in large lumps, is to add decoctions of the

cereals. Those which contain the least starch are to be preferred,—barley where there is a tendency to diarrhœa, oatmeal in cases of constipation. Schiffer, Korowin, and Zweifel have proved that infants, even from birth, can transform small amounts of starch into sugar by the action of the saliva. Beginning with the fourth week, the pancreatic secretion also possesses diastatic properties. "Not only does amylum save feeding with albuminoids (Voit), the excess of which leads so easily to intestinal putrefaction; not only is it, together with other carbohydrates, the principal source of muscular force in general and of the heart in particular (mainly in the acute diseases and probably better than alcohol); but it (amylum) also acts as a direct intestinal antiseptic."

The physiological effect of sodium chloride is very important, no matter whether it is directly introduced through the woman's milk or added as a condiment to cow's milk; the latter contains more potassium than sodium, and ought never to be given without the addition of table salt. There is no better protection to the epithelia and cell fluids than sodium chloride. Excretion and secretion are to a great extent rendered safe by it; it serves directly as an excitant to the secretion of the gastric glands and facilitates digestion. Another very important fact is this: the addition of sodium chloride prevents the solid coagulum of milk by either rennet or gastric juice. Therefore it should always be added to mixtures of cow's milk, and should also be given in cases nourished on the breast, if the mother's milk behaves like cow's milk in regard to solid curdling. Where decoctions of cereals are used, the percentage of salt should be much higher.

It is to be questioned how much alkalization can be effected by the addition of lime-water in five per cent. strength (as commonly advised). At 59° F. it contains 0.17 per cent. of lime, in rising temperatures less, and at the boiling point 0.13 per cent. An experiment with good cow's milk showed that lime-water failed to overcome acidity.

To render milk distinctly alkaline with sodium bicarbonate may be a grave error. The very bacilli which, with their spores, resist boiling to an unusual degree thrive best in an alkaline milk.

The new-born should have its milk boiled, sugared, salted, and mixed with from four to five times its amount of barley-water. At six months give equal parts. Gum arabic and gelatin are also useful, not only as diluents but also as nutrients. No single method is to be considered infallible; each case has its own requirements.

After boiling, milk should be kept in a clean bottle containing from three to six ounces, filled to the cork and inverted in a cool place. Before being used, it should be heated on a water-bath. By repeating this heating of the whole amount several times a day, fermentation will be retarded and the digestibility of the milk improved.

STARR.[133] Success in hand feeding depends on the administration as well as on the proper modification of the cream and milk mixtures,—*i.e.*, care of the bottle, nipples, etc. The separate preparation of each meal is important, as changes occur in the food if it is all mixed at the same time. The child should occupy a half reclining position when nursing, to prevent air from being swallowed, and from five to fifteen minutes should be allowed for each meal. Even the youngest infants require water several times a day, and the necessity increases with age. During the summer water cooled with ice may be allowed without harm; at other times water should not be too cold.

To render cow's milk as nearly like human milk as possible it is necessary to reduce the percentage of casein, to increase the proportion of fat and sugar, and to overcome the tendency of the casein to coagulate in large masses. To accomplish this we dilute with water, add fat in the form of cream, and either cane-sugar or lactose. The latter is greatly to be preferred to cane-sugar, as it is less apt to ferment and contains the salts

Diet for a Healthy Child during the First Fourteen Months.

	First week.	Second to sixth week.	Sixth to twelfth week.	Third to sixth month.	Sixth to seventh month.	Eighth to ninth month.	Tenth to fourteenth month.
Cream	2 teaspoonfuls	2 teaspoonfuls	½ ounce	½ ounce	½ ounce	½ ounce	½ ounce
Milk	....	½ ounce	10 drachms	2 ounces	3½ ounces	6 ounces	7½ ounces
Whey	3 teaspoonfuls	....	....	....	....	....	....
Water...........	3 teaspoonfuls	1 ounce	10 drachms	1½ ounces	2 ounces	1½ ounces	1½ ounces
Lactose..........	20 grains	20 grains	½ drachm	1 drachm	1 drachm	1 drachm	1 drachm
Salt	....	A pinch	A pinch	A pinch	A pinch	A pinch	....
Hours for feeding..	5 A.M. to 11 P.M.	5 A.M. to 11 P.M.	5 A.M. to 11 P.M.	5 A.M. to 10.30 P.M.	7 A.M. to 10 P.M.	5 meals daily	5 meals daily
Intervals..........	2 hours	2 hours	2 hours	2½ hours	3 hours	....	....
Total amount......	12 ounces	17 ounces	30 ounces	32 ounces	36 ounces	40 ounces	48 ounces

of milk, which are of nutritive value. Starr recommends the use of lime-water, one to three, as it causes clotting of the casein to take place more slowly and in smaller masses. A saccharated solution of lime is even better than lime-water. Instead, from two to four grains of sodium bicarbonate may be used to each bottle.

Starr believes that barley-water and other attenuants act mechanically by preventing the agglutination of casein particles in large masses. The former, to be efficient, should be used in the same proportion and in place of water. Gelatin may also be used. Except when employed as mechanical diluents, starches should not be used before the fourth month, since they differ so materially from human milk in composition that they are apt to lead to digestive disturbances.

At the second, third, and fourth meals two teaspoonfuls of a reliable infant's food may be added, the milk-sugar being omitted. Baked wheat or barley flour may be used instead if there is a tendency to diarrhœa.

We may give as substitutes for cow's milk equal parts of veal broth and barley-water, or of whey and barley-water plus a small amount of lactose; also a teaspoonful of raw beef juice diluted. Sometimes it is sufficient in cases of indigestion towards the end of the first year to reduce the strength of the food to that suited for a child from two to three months younger.

STARR.[135] "Laboratory Milk is theoretically the most perfect substitute for normal human milk that science has yet devised. But unfortunately clinical experience, in my own practice at least, does not bear this theory out." The following is a generalization of the results of over two years' study of the use of Laboratory Milk in substitute feeding.

I. Three cases could be termed satisfactory,—*i.e.*, healthy infants continuously fed on Laboratory Milk from shortly after birth to the time of beginning mixed diet.

II. Sixteen cases were partially satisfactory,—*i.e.*, infants in whom Laboratory Milk was used for some time—from six

months to a year—without producing active illness, but gradually inducing unhealthy conditions which necessitated a change of food.

III. Thirty-five cases were unsatisfactory,—*i.e.,* infants in whom Laboratory Milk had to be discontinued on account of the onset of some acute disorder of undoubted dietetic origin.

The unhealthy conditions referred to in the second class presented a very uniform group of symptoms,—namely, pallid, dry skin; dry, lustreless hair; soft, flabby muscles; indifferent appetite; inactive, not decidedly constipated, bowels; clay-colored evacuations; light-colored urine; listlessness and disinclination to play; peevishness and restless sleep—in a word, the features of malnutrition. With the flabbiness there is not always emaciation, but the two conditions are often associated.

Although scurvy is an exceptional result of laboratory feeding, Starr has personal knowledge of one undoubted case in which orange juice removed the symptoms, but where the child did not thrive until placed on a domestic mixture.

Why should a food which so nearly approaches breast-milk in its composition, which is uniform in its make-up, sterile, and easily and accurately modified to meet digestive emergencies,—why should it fail when put to a clinical test? Starr thinks that it is due to the destruction of the natural fat emulsion by the use of the separator. In some way the digestibility of the proteids is diminished, thus giving rise to malnutrition or to irritative diarrhœa. Starr has never seen an infant below the age of ten months who could tolerate a laboratory mixture containing over one and a half per cent. proteids, and has often encountered cases where at the age of two months or more a percentage of 0.50 proteids was not digested. "When unseparated milk is the basis of our mixture, and we have a natural emulsion to deal with, the proteids are much more easily digested, so that a badly nourished child of ten months, in whom Laboratory Milk percentage cannot be forced higher

than 1.5 proteids, will easily digest and grow strong upon a domestic mixture containing proteids 2.97 per cent., sugar 4.94 per cent., and fat 3.75 per cent." Of course the same care must be taken in home modification to secure pure, clean milk and cream from healthy, well-tended cows. Pasteurization can be carried out at the home, and accurate measurements of the food quantities and cleanliness of the vessels and bottles can be obtained. The daily variations in the milk and cream Starr considers a minor detail of questionable importance when compared with the destruction by the separator of the chemical combinations present in milk. We certainly should not sacrifice everything to chemical accuracy.

He does not wish to be understood as condemning Laboratory Milk absolutely. Its introduction has greatly advanced substitute infant feeding by drawing attention to the importance of cleanliness and accuracy in the quantity and composition of milk formulæ. It has placed the whole question on a higher scientific plane than had ever been reached before.

HOLT.[183] The following principles form the basis of all methods for the scientific feeding of infants:

"I. Mother's milk is not only the best, it is the only ideal infant food.

"II. Any substitute should furnish the same constituents,—namely, fat, sugar, proteids, salts, and water; furthermore, they should be in about the same proportions as they exist in woman's milk.

"III. As nearly as possible the different constituents should resemble those of mother's milk both in their chemical composition and in their behavior to the digestive fluids.

"IV. These conditions are fulfilled only by fresh milk from some other animal.

"The central thought of the *American* or *percentage system* of feeding is to consider the different elements of the food separately and to adapt their proportions to the child's digestion. . . It aims to discover the proper proportion of fat,

sugar, and proteids and the best methods of gradational increase for healthy infants with normal digestions, and also to discover for those with abnormal or feeble digestion the combinations best suited to the individual conditions."

Since one element of the milk alone may be at fault, it is often sufficient to reduce its proportion without reducing the proportions of all the elements or entirely giving up the use of milk.

Fat.—The average amount of fat which a healthy infant can digest is one per cent. on the second day, two per cent. at one week, increased to three per cent. at three or four weeks and to four per cent. at four or five months.

Sugar.—It is seldom necessary to reduce the sugar percentage below five or to exceed seven, the quantity present in mother's milk. As the sugar in milk is simply lactose in solution, it is only necessary to calculate the amount required to bring the percentage up to that desired. The milk-sugar must be filtered through absorbent cotton if it contain impurities, and dissolved in boiling water; it must be prepared fresh every day in summer and every second day in winter. If good milk-sugar cannot be obtained, cane-sugar may be substituted; but little more than half the quantity is needed as compared with milk-sugar on account of its greater sweetness and greater liability to ferment in the stomach. In exceptional cases cane-sugar or maltose is better borne than lactose.

Proteids.—The proteids give the most trouble to the infant's digestion. In the first few days their proportion should be reduced to from 0.33 to 0.50 per cent. The secret of success is to reduce the proteids at the start to such proportions as the infant can easily digest, then gradually to increase the quantity. At the end of the first month the average child can take one per cent., from two to three months one and a half per cent., and from four to five months two per cent. This reduction in proteids is effected by dilution with water. Except to start with too high proteids, no more common mistake is

made than to continue too long with too low proteids. Anæmia, malnutrition, and not infrequently scurvy result from this practice.

Diluents.—Barley-, rice-, and oatmeal-water are convenient forms in which starch may be added to the food of infants who are old enough to be able to digest it,—*e.g.*, from seven to eight months. More diluted, they may be used to allay thirst when the stomach is irritable and all forms of milk must temporarily be withheld. Rice-water or barley-water is usually preferable when there is diarrhœa, and oatmeal-water when there is constipation. It is questionable whether barley-water is superior to plain water as a diluent; in some cases it certainly seems to be useful.

Salts.—Like the proteids, inorganic salts are in excess in cow's milk, and in nearly the same proportion, so that the dilution of the one causes that of the other.

Reaction.—The acidity of cow's milk may be overcome by the addition of either lime-water or sodium bicarbonate. Of the former, one ounce is enough for twenty ounces of the milk mixture; of the latter, one grain to each ounce is sufficient. For very young infants it is often desirable to add twice as much lime-water.

Milk-Laboratory.—The establishment of the milk-laboratory is a great stride in advance in infant feeding, since it becomes possible to vary any one of the constituents of the food separately until the combination is reached which is suited to the infant's digestion. It is also a decided advantage to know that the child is getting exactly what has been ordered, and not to have to put up with the ignorance or carelessness of the mother or nurse who otherwise would prepare the food. The main objection to Laboratory Milk has been its expense. Holt does not consider that there is any difference in the digestibility of centrifugal and gravity cream.

The following table represents the average percentages of proteids, sugar, and fat which the healthy infant can take:

Age.	Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.	Amount at each feeding. Ounces.	No. of feedings in 24 hours.	Interval by day in hours.
Premature infants	1.0	4.0	0.25	$\frac{1}{4}$–$\frac{3}{4}$	12–18	1–1$\frac{1}{2}$
First to fourth day....	1.0	5.0	0.3	1–1$\frac{1}{2}$	6–10	2–4
Fifth to seventh day...	1.5	5.0	0.5	1–2	10	2
Second week..........	2.0	6.0	0.6	2–2$\frac{1}{2}$	10	2
Third week...........	2.5	6.0	0.8	2–3$\frac{1}{2}$	10	2
Fourth to eighth week.	3.0	6.0	1.0	2$\frac{1}{2}$–4	9	2$\frac{1}{2}$
Third month	3.0	6.0	1.25	3–5	8	2$\frac{1}{2}$
Fourth month........	3.5	7.0	1.5	3$\frac{1}{2}$–5$\frac{1}{2}$	7	3
Fifth month..........	3.5	7.0	1.75	4–6	7	3
Sixth to tenth month..	4.0	7.0	2.0	5–8	6	3
Eleventh month	4.0	5.0	2.5	6–9	5	4
Twelfth month	4.0	5.0	3.0	7–9	5	4
Thirteenth month.....	4.0	4.5	3.5	7–10	5	4

Home Modification of Milk.

Holt considers that three and a half per cent. proteids is more nearly the correct average of the mixed milk of a herd than four per cent., the average ordinarily given. The following table, based on analyses by Adriance and others, represents pretty accurately the composition of creams of different density:

	I. Per cent.	II. Per cent.	III. Per cent.	IV. Per cent.	V. Per cent.
Fat........................	4.00	8.00	12.00	16.00	20.00
Sugar......................	4.50	4.35	4.20	4.05	3.90
Proteids...................	3.50	3.40	3.30	3.20	3.05
Salts......................	0.75	0.70	0.65	0.60	0.55

Since in most modifications of milk the fat must be considerably higher than the proteids, it may be introduced by the addition of cream or by using top milk.

A series of experiments (one hundred and ten analyses) at the Walker-Gordon farm have shown that if mixed milk be immediately bottled and cooled, *after four hours* the upper fourth will contain nearly all the fat, which will rise as cream, and the upper layers will have nearly the same percentage of fat whether the milk has stood for four hours, for eight hours, or overnight.

	After four hours. Per cent. of fat.	After eight hours. Per cent. of fat.	Overnight. Per cent. of fat.
Upper four ounces........	20.50	21.25	22.00
Second four ounces	6.00	6.50	6.50
Third four ounces	1.50	1.40	1.00
Fourth four ounces	1.20	1.00	0.30
Fifth four ounces.........	1.00	1.00	0.05

Using standard milk containing four per cent. fat, we can secure approximately the following results:

	Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.
Sixteen ounces, or the upper half, furnish	7	4.40	3.40
Eleven ounces, or the upper third, furnish.....	10	4.30	3.30
Eight ounces, or the upper fourth, furnish.....	13	4.15	3.25
Six ounces, or the upper fifth, furnish.........	16	4.05	3.20

If the milk we are using is rich in fat (five per cent. or over), from two to three ounces more should be removed for each formula; if it is poor in fat (from three to three and a half per cent.), about two ounces less than the amount specified should be used.

The three formulæ which are most useful are: (1) Those where the fat is three times the proteids. (2) Those where the fat is twice the proteids. (3) Those where they are about equal.

Series A.—Ratio of fat to proteids, three to one.

Primary formula (ten per cent. milk): fat ten per cent., sugar 4.30 per cent., proteids 3.30 per cent. Obtained (1) by using the upper one-third of bottled milk, or (2) by using equal parts of milk (four per cent.) and cream (sixteen per cent.).

Derived Formulæ giving Quantities for Twenty-Ounce Mixtures.

Milk-sugar ....one ounce.
Lime-water........................one ounce.
Boiled water ....to make twenty ounces.

		Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.
I.	With one ounce of ten per cent. milk ...	0.50	5.20	0.17
II.	With two ounces of ten per cent. milk ..	1.00	5.40	0.33
III.	With three ounces of ten per cent. milk.	1.50	5.60	0.50
IV	With four ounces of ten per cent. milk..	2.00	5.85	0.66
V.	With five ounces of ten per cent. milk...	2.50	6.05	0.83
VI.	With six ounces of ten per cent. milk ...	3.00	6.25	1.00
VII.	With seven ounces of ten per cent. milk.	3.50	6.50	1.20

To make twenty-five ounces, add one-fourth more of all the ingredients; to make thirty ounces, add one-half more.

Series B.—Ratio of fat to proteids, two to one.

Primary formula (seven per cent. milk): fat seven per cent., sugar 4.40 per cent., proteids 3.40 per cent. Obtained (1) by using the upper half of bottled milk, or (2) by using three parts milk (four per cent.) and one part cream (sixteen per cent.).

Derived formulæ giving quantities for twenty-ounce mixtures. Amount of milk-sugar, lime-water, and water as above.

		Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.
I.	With one ounce of seven per cent. milk..	0.35	5.20	0.17
II.	With two ounces of seven per cent. milk.	0.70	5.40	0.35
III.	With three ounces of seven per cent. milk	1.05	5.60	0.52
IV.	With four ounces of seven per cent. milk.	1.40	5.80	0.70
V.	With five ounces of seven per cent. milk.	1.75	6.00	0.87
VI.	With six ounces of seven per cent. milk..	2.10	6.20	1.05
VII.	With seven ounces of seven per cent. milk	2.45	6.45	1.22
VIII.	With eight ounces of seven per cent. milk	2.80	6.70	1.40
IX.	With nine ounces of seven per cent. milk.	3.15	6.90	1.55
X.	With ten ounces of seven per cent. milk..	3.50	7.10	1.75
XI.	With eleven ounces of seven per cent. milk	3.85	7.30	1.92
XII.	With twelve ounces of seven per cent. milk	4.15	7.50	2.07

Series C.—Ratio of fat to proteids, eight to seven.

Primary formula (plain milk): fat four per cent., sugar 4.50 per cent., proteids 3.50 per cent.

Derived formulæ giving quantities for twenty-ounce mixtures. Amount of milk-sugar, lime-water, and water as above.

		Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.
I.	With two ounces of four per cent. milk ..	0.40	5.40	0.35
II.	With four ounces of four per cent. milk..	0.80	5.80	0.70
III.	With six ounces of four per cent. milk ...	1.20	6.20	1.05
IV.	With eight ounces of four per cent. milk .	1.60	6.70	1.40
V.	With ten ounces of four per cent. milk...	2.00	7.10	1.75
VI.	With twelve ounces of four per cent. milk	2.40	7.60	2.10
VII.	With fourteen ounces of four per cent. milk	2.80	8.10	2.45
VIII.	With sixteen ounces of four per cent. milk	3.20	8.50	2.80

When the formulæ contain from one-half to three-fourths milk, three-fourths of an ounce of milk-sugar is sufficient for each twenty ounces; if more milk is used, add only half an ounce of lactose.

The first year may be divided into three feeding periods: the first, from birth to the end of the third or fourth month; the second, from this time to the end of the tenth month; the third, the rest of the first year. During the first period the best results are obtained when the fat is three times the proteids; during the second period, when the fat is twice the proteids; during the third period, when the two are nearly equal.

General Rules for varying Milk Percentages.—No schedule for infant feeding can be followed with absolute regularity, since in each case the individual factors must be taken into account, such as the age, weight, condition of the digestive organs, etc. An infant that at four months weighs as much as the average infant at eight months will usually be able to take a quantity of food and also the percentage advised for the latter age. Again, there are many cases in which the percentages of the milk must be increased more slowly than the schedule, but the same gradational steps of increase may advantageously be followed with all cases.

During the first two or three weeks of life no material gain in weight is to be expected while the infant is taking mixtures with very low percentages. This condition may be considered entirely satisfactory, provided the child is comfortable and shows no signs of indigestion; the strength of the food may gradually be increased with the demands of the child's appetite, and gain in weight will usually follow after a short time. "Nothing is easier than to derange the organs (of digestion) during the first weeks by too high percentages, and such disturbances, even though they appear trivial, often continue for many weeks."

A caution is necessary against changing the formulæ too frequently, since it is not possible to determine the infant's ability to digest a certain mixture short of at least two days.

Special Symptoms.—The frequent regurgitation (often one or two hours after feeding) of sour curdled milk or a watery

fluid is usually an indication that the proportion of fat is too high. The first indication is to reduce the amount of fat; other modifications which may be useful are to give double the amount of lime-water (ten per cent.) or to reduce the sugar percentage. It is important that the food be taken slowly, that the child be kept perfectly quiet after feeding, and that the intervals between feedings be longer than in the case of good digestion.

Constipation during the first weeks of life, unless associated with manifest discomfort on the part of the child, should be disregarded, especially if the odor and color of the discharges are nearly normal. It is a mistake to increase the fat percentage rapidly, since in a few days, when the proportions of the proteids and the fat are gradually increased according to the schedule, this form of constipation will pass away. "Anything higher than three per cent. of fat during the first four or five weeks almost always works badly; over four per cent. at any time during the first year can seldom be long continued without disturbing digestion." If constipation persists with these percentages, it is better to adopt other measures for its relief than to further increase the fat. "The habitual colic of early infancy is almost invariably due to too high proteids, and rarely occurs when percentages as low as those above advised are given."

"The appearance of curds in the stools is usually associated with colic and constipation; it is commonly due to too high proteids or to inability to digest the proteids given, even though the percentages are not high." Loose green or yellowish-green stools of a sour odor are sometimes caused by too high a percentage of sugar, but more often by an excess of fat. There are usually from two to five stools a day resembling thin scrambled eggs. The small yellowish masses are often mistaken for curds. Stools such as those described are often seen in nursing infants as well as in those artificially fed, and the condition is not incompatible with steady and regular gain in

weight. After it has persisted any length of time mucus is regularly present and an intractable intestinal catarrh may be produced. Large dry, white, or gray stools, which are often smooth, are generally due to an excess of fat. They have usually a peculiarly foul odor owing to the presence of fatty acids, and may be distinguished from curds by their solubility in ether and by their burning readily with the odor of butter.

Feeding of Difficult Cases.—These cases include those infants who do not gain in weight (or whose gain is irregular. —EDITORS) and who habitually suffer from indigestion. The great majority result from previous improper feeding or equally improper nursing. "These cases are serious, since in most of them nothing can be accomplished without close and continuous personal observation. They do not tend to right themselves, and the infant's life is often sacrificed as the result of bad management." In the management of such a case we must not only ascertain the previous methods of feeding, but also investigate thoroughly the way in which the food has been prepared and administered (the condition of the nipples and bottles, the time between meals, cleanliness, etc.).

Although some children do better with shorter intervals and smaller quantities, generally speaking, the intervals should be longer than in health. It is seldom wise to make them less than three hours for young infants or less than four hours for those who have passed the eighth or ninth month. When symptoms make a reduction in the food necessary, whether in quantity or strength, it should in most cases be radical to produce any decided effect. On the other hand, in increasing either the strength or the quantity of the food, the changes must be made very gradually, lest we overtax the sensitive digestion.

"In troublesome protracted cases it is better, as a rule, to go to the opposite extreme from that which has previously been tried; large feedings should take the place of small feed-

ings, long intervals of short, and a stronger food may succeed one which is very dilute."

An infant who has been long fed on farinaceous foods will probably improve when these are stopped entirely and suitable percentages of cow's milk are given. On the other hand, it may be necessary temporarily to withdraw milk in any form. "Such a course is often better than wasting time in juggling with fractional milk percentages when one or two intelligent trials have been entirely unsuccessful."

In modifying milk for difficult cases, it is rarely necessary to reduce the sugar below four per cent.; it should never be given above seven per cent. It is not often that the fat can be raised above three per cent. in cases of feeble digestion, even when they are over six months old. For younger infants "two per cent. is as much as it is wise to give, if there is any disposition to vomiting or regurgitation. Where such symptoms are prominent, it may be necessary for a time to reduce the fat to one and a half or even to one per cent." Infants suffering from marasmus have a special difficulty in digesting the fats, while it is a common practice to give them in large proportions.

In no class of cases is it more important to begin with low percentages of proteids than in those with naturally feeble powers of digestion. Disturbance is pretty sure to result if we begin by administering one or two per cent. of proteids to a very young infant. On the other hand, if we begin with 0.33 or 0.50 per cent. proteids and gradually increase, there is seldom any trouble.

In dealing with infants whose digestions have already been upset, "it is usually wise to begin by reducing the percentage of the disturbing element—fat or proteids—to a point where the child's most obvious symptoms of disturbance disappear, and then gradually but very slowly to increase, but to go no faster than the child's digestion will warrant, regardless of his appetite." It is impossible to feed these cases like healthy

children and equally impossible to tell in advance, until one has tried, just what mixture will succeed.

Holt believes that in some cases the addition of the cereal gruels to the milk is "of material assistance in the digestion of the milk proteids." He prefers those made from prepared flours which need only from twenty to thirty minutes' cooking. The strength should be one rounded tablespoonful to a pint of water. "A caution should be given against using too large a quantity of plain or even dextrinized gruels, for in this way the flatulent intestinal indigestion among the children of the poorer classes is frequently produced."

In some cases in which fat and proteids are very difficult of digestion, owing either to acute or chronic gastro-intestinal derangements, it may become necessary to give temporarily a food composed almost entirely of carbohydrates, either farinaceous or malted foods. This may be continued for from a few days to two or three weeks, according to the severity of the symptoms; but we must return as soon as possible to a milk diet, beginning with the smallest proportions of milk, or whey, or even condensed milk.

For difficult cases during the second year, milk should be the principal diet, modified as for healthy infants from eight to twelve months younger than the patient under treatment. Peptonization may be required even when the percentage of casein is not high. The daily quantity should generally be somewhat larger than for a young healthy infant taking food of the same strength. The interval should never be shorter than three hours, and in many cases four hours are to be preferred.

ROTCH.[119, 253] With regard to the problem of infant feeding, Rotch remarks that "the present is a most opportune time to raise a note of warning against allowing our enthusiasm over any one especial theory to warp our better judgment. There will surely be a reaction which will relegate to its proper place every theory built upon single factors of the problem before

us, and which is actually doing harm by keeping in the background other theories which, each in its own sphere, as a significant part of the whole, may be of very great importance in the successful solution of the general problem. Our scientific knowledge and clinical investigations have not yet enabled us to follow nature exactly, and we therefore have not yet obtained an ideal method of substitute feeding. We must, nevertheless, go as far as the present state of our knowledge will allow, thus gaining a little ground every year, and we must be especially careful not to be led astray by the fictitiously brilliant results which are reported from time to time in favor of certain foods."

The mortality resulting from the use of various infant foods always remains far above that from the employment of human breast-milk.

Rotch is convinced that the choice of a suitable food is only part of the problem of infant feeding; we must not neglect to "investigate and carry out in detail" the other *general factors,* neglect of which has had much to do with our failures with substitute feeding in the past.

"Assuming, then, that the average breast-milk is the safest standard for us to copy," we can at once select the milk of the cow as the most available substitute from which to obtain the elements of our artificial food. The milk of other animals may approach more nearly in its composition to that of human milk. Apart from the impossibility of obtaining it in sufficient quantity, however, any milk will require some modification, and "it is as easy to change the proportions of the different constituents to a great degree as to a small."

The general factors which Rotch considers of such importance in the preparation of an infant food may be tabulated:

(1) A pure milk obtained from healthy cows, under proper hygienic precautions (see Chapter IX.).

(2) An alkaline reaction, which usually requires the addition

of an alkali, this being the only foreign element that it has been found necessary to employ.

(3) Thorough dilution of the food with water, as is found in human milk. Rotch prefers plain water to decoctions of starch.

(4) The use of lactose to increase the sugar content. Cane-sugar, which some authors prefer, seems to act as a preservative in a concentrated form, as it is found in condensed milk; but when it is diluted it ferments very readily. Milk-sugar undergoes no direct alcoholic fermentation, but quickly changes to lactic (possibly acetic) acid in the presence of nitrogenous ferments, while cane-sugar easily undergoes alcoholic fermentation, but changes to lactic acid less readily than milk-sugar; cane-sugar, moreover, takes on butyric acid fermentation more readily than does milk-sugar. So far as is known, cane-sugar is merely a reserve and cannot be used directly for nutrition, for which milk-sugar may possibly have a direct value. Finally, reasoning from analogy, we should say that as milk-sugar is the only form of sugar found in the milk of mammals, it is there for some good purpose, and that it is needed for the accomplishment of some process which takes place after the food has been swallowed.

(5) The proper modification of the fat and proteids of cow's milk to suit the needs of the individual case.

(6) The avoidance of starch. As woman's milk does not under any circumstances contain starch, and as the function of converting starch is in the process of development during the first ten or twelve months of life, and should therefore not be taxed, Rotch believes that starch should not form part of the infant's food in the early months of life.

(7) The greatest care to secure absolute cleanliness of the nursing-bottles and nipples; the latter should be renewed frequently.

(8) The adoption of uniform intervals between the feedings.

(9) The amount of food to be given at each feeding must be carefully regulated according to the gastric capacity. Frequently this does not correspond with the weight of the infant, yet the weight is undoubtedly of the greatest importance in determining the proper amount of food to be given during the early months of life. At this time it is especially necessary to avoid stretching an organ so easily distensible as is the infant's stomach, so that it is wiser to give too little rather than too much food.

The following table is based on measurements of a large number of infants' stomachs.

General Rules for Feeding during the First Year.

Day feedings begin at six A.M. and end at ten P.M.

Age.	Intervals of feeding. Hours.	No. of feedings.	No. of night feedings.	Amount at each feeding. Cc.	Total in twenty-four hours. Cc.
One week	2	10	1	30	300
Two weeks	2	10	1	45	450
Four weeks	2	9	1	75	675
Six weeks	2½	8	1	90	720
Eight weeks	2½	8	1	100	800
Three months	2½	7	0	120	840
Four months	2½	7	0	135	945
Five months	3	6	0	165	990
Six months	3	6	0	175	1035
Seven months	3	6	0	190	1140
Eight months	3	6	0	210	1260
Nine months	3	6	0	210	1260
Ten months	3	5	0	255	1275
Eleven months	3	5	0	265	1325
Twelve months	3	5	0	270	1350

Ssnitkin, in a series of careful investigations at the Children's Hospital at St. Petersburg, determined the amount of

food required during the first months of life. He concluded that "the greater the weight the greater the gastric capacity." To calculate the amount needed take $\frac{1}{100}$ of the initial weight of the infant and add one gramme to each day of life; for example, if the initial weight is three kilogrammes, $\frac{1}{100}$ of this will be thirty grammes. At fifteen days, therefore, give thirty plus fifteen, or forty-five grammes.

Rotch considers that it is best to secure first of all the proper digestion of the food, even should there be no gain in weight, and then to increase the percentages of the different elements. Sometimes marked hunger requires a sudden increase in the quantity of food. This may be due to rapid growth of the infant's stomach, which in some cases is out of proportion to the age and size of the child.

Milk-Laboratories.

The long-felt desire that the subject of infant feeding should be reduced to a more exact system has led Rotch to give his professional assistance to the establishment of milk-laboratories, which have become so well known.* They enable the physician to prescribe the infant's food exactly as he prescribes its medicine. In this way, when lacking in success, he can be sure that it is the fault of the food he is giving, and not because the food has varied from what he supposed he had ordered. No one mixture will in all cases prove successful, but a great variety in the percentages of the different elements of the milk will be needed in substitute feeding just as they already exist in maternal feeding. This explains the diversity of results obtained in the past with the same food by different practitioners.

The laboratory should be situated in a healthy locality, and

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* The first milk-laboratory for the exact modification of milk was opened in Boston in 1891 under the name of the Walker-Gordon Laboratory.

every aseptic precaution taken to avoid the presence or development of pathogenic germs. The milk-rooms where the milk is received from the farm should be cool, free from dust, and isolated as far as possible from the other parts of the laboratory. There should also be an entirely separate room in which the boxes and bottles returned by the consumer can immediately be sterilized in an apparatus reserved for this purpose.

The modifying materials used in the laboratory should be carefully kept in glass vessels, at a temperature of about 4.4° C. (40° F.), in order to prevent the growth of bacteria. This is preferable to using materials in which the bacteria have been destroyed by heat. Separate rooms should be provided for the separation of milk and for its modification, and the office of the laboratory must also be apart from the working-rooms. It is also necessary that all odors be carefully excluded from the milk-rooms, as they are so easily absorbed by milk. Finally, the employees must be of sufficient intelligence to take a proper amount of interest in their work.

As a result of the special care observed in the selection and feeding of the cattle on the Walker-Gordon farms, Laboratory Milk may be said to have an almost uniform percentage of its own at all times of the year.

The first step towards its modification is to separate it into cream and skim milk. The separating-room has an asphalt floor and walls of white tile, which are kept moistened and free from every kind of dirt and dust. The air is kept constantly pure by a ventilator. The centrifugal separator removes practically all of the fat from the milk except a small fraction (0.13 per cent.). It accomplishes two very important results: first, it separates from the cream and milk any dirt or foreign matter present, and secondly, the resulting cream has an almost stable percentage of fat (sixteen per cent.). The distilling apparatus is also kept in the separating-room.

In Laboratory Milk the percentage of fat, proteids, sugar, and salts is not apt to vary appreciably, but the percentage of fat in the milk of individual cows differs from day to day and thus slightly affects the amount of fat present in the milk of the herd. To determine the fat percentage we use the Babcock milk-tester. In this apparatus the fat of the milk, previously acidulated, is completely separated by centrifugation at a high temperature. This gives the daily percentage of fat in the whole milk, as the sample has been taken from the mixed milk of the entire herd. Since the exact percentages of the constituents in the cream and separated milk are determined each day, it is easy to calculate the proportions of each which are required to fill a given formula.

A physician can write for an exact prescription containing so much proteids, sugar, fat, and salts, and be as sure of obtaining it as he is of any medical formula which is filled at a pharmacy. These prescriptions are filled by "modifying clerks," each of whom has at hand jars, with tightly fitting covers, containing the necessary ingredients,—namely, cream, separated milk, a carefully prepared twenty per cent. lactose solution, freshly made lime-water, and for older infants preparations of oats, barley, and wheat. The feeding-tubes or bottles, the exact size and number of which are specified in the prescription, are filled by the clerks according to the required formula, stoppered with sterile non-absorbent cotton, placed in racks or baskets designed to hold the number that is needed, and are then ready to be sterilized. The rule of absolute cleanliness is carried out in every possible detail. from the table on which the materials are combined to the dress and hands of the clerks.

The sterilizer, which is placed in the separating-room, is so arranged that the steam which passes through it can be regulated so as to produce any degree of heat required up to 100° C. (212° F.). After the food has been sterilized (as

a rule, from twenty to thirty minutes) the baskets are placed in a cooling tank, where the temperature of the food is reduced to 13.3° C. (38° F.). They are then quickly delivered to the consumers.

The baskets and bottles, when returned, are taken directly to the wash-room, which is entirely shut off from the rest of the laboratory, as before mentioned. Here they are thoroughly sterilized and washed; the tags and stoppers are destroyed.

The prescription blank which is used at the Walker-Gordon Laboratory, to be filled out by the physician, is arranged as follows:

℞ Per cent.	
Fat	Reaction..................
Milk-sugar................	Number of feedings...... ..
Proteids	Amount at each feeding....
Mineral matter....	Heated for................
Lime-water	Heated at........... .....
Special directions.	Remarks.
For whom ordered.	Infant's age........... ..
	Infant's weight ....
	Signature.
Date.	M.D.

It will be seen that the above blank allows the physician to prescribe exactly as he sees fit and to regulate the degree of heat employed in the preparation of the milk. The percentage of mineral matter requires, as a rule, no modification other than that produced by the dilution. If a slightly alkaline reaction be desired, the amount of lime-water can be left to the discretion of the modifying clerk without distinctly specifying it.

The prescriptions, when received, are copied into a book in the office of the laboratory, and are then translated into such a form as can readily be understood by the modifying clerk.

The following table shows the practical limits of milk-modification which can be accomplished at the laboratory.

I. Low Fats.

	Per cent.	Per cent.	Per cent.	Per cent.
Fat..........	0.03	0.04	0.08	0.12–0.16
Sugar........	2.00	3.00	4.00–5.00	6.00–7.00
Proteids......	0.75	1.00	2.00	3.00–4.00

II. Low Sugars.

	Per cent.	Per cent.	Per cent.	Per cent.
Sugar........	0.87	1.40	2.12	3.50–4.30
Fat..........	2.00	3.00	3.50	4.00
Proteids......	0.75	1.00	2.00	3.00–4.00

III. Low Proteids.

	Per cent.	Per cent.	Per cent.	Per cent.
Proteids......	0.22	0.34	0.45	0.53
Fat..........	2.00	3.00	4.00	4.50
Sugar........	2.00	3.00	4.00–5.00	6.00–7.00

Home Modification.

When it is impossible to obtain Laboratory Milk, Rotch advocates the following method of home modification, presupposing an ordinary degree of intelligence on the part of the mother.

The necessary implements are as follows:

(*a*) A sterilizer, which is simply a tin can large enough to contain the required number of nursing-bottles. It can be heated on the stove or, if elevated on legs, by an alcohol lamp. The top is perforated for the introduction of a thermometer, so that the exact temperature of its contents can be ascertained at any time. The tubes in which the milk is sterilized are simply the ordinary oblong graduated feeding-bottles, so constructed as to possess no corners, the bottom being rounded, not flat. These are stoppered with non-absorbent cotton.

(*b*) A metal rack for holding the bottles, which can be

lowered into the sterilizer; the latter is then filled with water to the level of the milk in the tubes.

(*c*) A thick "cozy" is also to be provided, as well as (*d*) a glass graduate holding two hundred and fifty cubic centimetres (eight and one-third ounces) and (*e*) a sugar measure holding 13.5 grammes (three and three-eighths drachms) of lactose. Finally, there must be (*f*) a glass siphon or tube bent into the shape of the letter U, for the removal of the milk from the jar without disturbing the cream.

The mother should be made to understand the importance of obtaining a milk of good quality from a reliable dealer.

As soon as the milk is delivered, the jar should be placed in ice-water (to which a teaspoonful of salt should be added for each quart of water) and left for six hours, care being taken not to allow the temperature of the water to fall below 35° F. At the end of this time the lower twenty-four ounces of the milk in the jar is siphoned off. The remaining eight ounces of cream will contain about ten per cent. of fat. With the cream, milk, milk-sugar, a fresh solution of lime-water, and some plain boiled water various modifications can be made, for which Rotch gives a number of tables. If the actual percentages of the fat and proteid constituents of the milk and cream be known, they can be combined according to some of the formulæ devised by Westcott, Baner, and others (see Chapter XIII.).

When the mixture is completed, the feeding-bottles are filled with the amount to be used at each feeding, placed in the rack, and lowered into the sterilizer, which is filled with water to the level of the milk in the bottles. The temperature can then be raised to any desired point short of 213° F. (Rotch employs 171° F.), after which the can is moved to the side of the stove and covered with the "cozy," which in a warm place should retain the heat, keeping the temperature between 167° and 170° F. for half an hour. The milk should then be placed in the ice-chest until used. If we wish to avoid

coagulating the lactalbumin, the temperature must not exceed 155° F.; this will kill most of the bacteria in milk. If the milk is to be carried long distances, fractional sterilization may be employed to destroy the spores of the bacteria.

Regarding the question whether the fat emulsion of milk which is used for modification is interfered with or destroyed by centrifugation, Rotch has found by microscopic examination that the emulsion of one of his mixtures corresponds almost exactly with that of the human milk which it was made to represent. So far as the emulsion is concerned, no injury is done by separating the elements of milk and then recombining them.

For a healthy infant born at term, of normal weight and development, Rotch regulates the quantity of food and time of feeding according to the table (page 142). During the first twenty-four to thirty-six hours he gives only small quantities of a five per cent. solution of lactose. During the first week he gives a mixture containing: fat two per cent., sugar five per cent., proteids from 0.25 to 0.75 per cent. This must have a slightly alkaline reaction and must be pasteurized at 75° C. (167° F.).

	Fat. Per cent.	Sugar. Per cent.	Proteids. Per cent.
Second week	2.5	6.00	1.00
Third week	3.00	6.00	1.00
Four to six weeks	3.50	6.50	1.00
Six to eight weeks	3.50	6.50	1.50
Two to four months	4.00	7.00	1.50
Four to eight months	4.00	7.00	2.00
Eight to nine months	4.00	7.00	2.50
Nine to ten months	4.00	7.00	3.00
Ten to ten and a half months	4.00	5.00	3.25
Ten and a half to eleven months	4.00	4.50	3.50
Eleven to eleven and a half months	Unmodified cow's milk		

At about the tenth or eleventh month Rotch usually begins to give one and then two meals daily of oat jelly and plain milk, pasteurized at 68° C., equal parts, with a pinch of salt added to suit the infant's taste. Barley or wheat may also be used. In the twelfth month he accustoms the infant to taking bread (one day old) and to eat with a spoon, so that at one year of age it takes bread and milk for breakfast and supper and oat jelly and milk for the three middle meals.

W. P. NORTHRUP [221] dwells on the importance of "clean" milk which is moderately free not only from bacterial contamination, but also from the products of their activities,—the toxins. The formation of the latter can be prevented by the immediate cooling of the milk, after it is drawn, to 40° F., at which temperature most bacteria cannot grow.

In Northrup's experience with centrifugal cream, "there has never arisen any accident or incident to raise objection to it." Moreover, its all-important freshness is an argument in its favor which it is difficult to overturn. He would limit the use of home modifications to those infants who are already well started and thriving and to those who are not to be considered as delicate or in a critical state. "For really difficult cases (critical cases), in which there is risk in trying things, in which it is necessary to find the right feeding at once, and in which the condition of the child is such that it is important not to risk any time, he has no hesitancy in saying that there is no feeding so reliable and so good as the modified milk." The only objection to the use of Laboratory Milk is its expense.

Northrup also insists that the physician should have a proper knowledge of what the infant requires at different periods of its life before he attempts to prescribe this or that formula.

The three most important formulæ to remember are: (1) Feeding for the new-born (proper for the majority): fat two per cent., sugar five per cent., proteids 0.75 per cent. (2) "Low average breast-milk:" fat three per cent., sugar

six per cent., proteids one per cent. (3) "High average breast-milk:" fat four per cent., sugar seven per cent., proteids two per cent. These modifications should be changed gradually and frequently, by small fractions, from one to another. From eight months to one year the proportions should be made to approximate cow's milk. The diet should be all milk for the first year and mostly milk for the second year.

Koplik [79] divides the cases under his observation in his dispensary service in New York City into two classes: (*a*) those who were fed from birth on modified cow's milk, and (*b*) those who were given the breast in addition to cow's milk. All were under nine months of age. The milk was sterilized at from 90° to 92° C. and rapidly cooled. The same mixture was given to all cases. It was composed of equal parts of cow's milk and distilled water, with six per cent. of crystallized milk-sugar,—the so-called Heubner-Hoffmann Mixture. Children under three months received ninety cubic centimetres; older children were given one ounce (thirty cubic centimetres) more for each month of their age till eight ounces (two hundred and forty cubic centimetres) were reached, when whole milk was used. Each child was given from seven to eight bottles a day. The mothers were told not to give more than one and a half ounces at a time to babies under one month. Systematic weighings were carried out.

The Heubner-Hoffmann Mixture contains: water 90.57 per cent., proteids 1.78 per cent., fat 1.85 per cent., sugar 5.44 per cent., and ash 0.36 per cent.

During the last five years this mixture proved satisfactory in the majority of cases. In a few cases the deficiency in fat was made up as follows: sixteen per cent. cream was added to each one hundred parts of the Heubner-Hoffmann Mixture, so as to make the fat content four per cent. We know that relatively larger quantities of cow's milk than of human milk are required for the healthy nutrition of infants; but there is no excessive consumption, even when quantities are taken

which are greater than the known capacity of the stomach (see Camerer's monograph, Vienna, 1898). The best results in feeding sickly infants were obtained with Biedert's minimal amounts.

Class A.—In thirty cases Koplik found an increase in weight: from first to second month, thirty-two grammes; second to third month, 17.4 grammes; third to fourth month, 23.6 grammes; fourth to fifth month, eighteen grammes; fifth to sixth month, 14.2 grammes; sixth to seventh month, 11.8 grammes; seventh to eighth month, 15.6 grammes; eighth to ninth month, 15.1 grammes. These were all dispensary cases from the lowest classes, whose hygienic surroundings were most unfavorable, and where the increase in weight was liable to be interfered with by frequent attacks of diarrhœa and other diseases.

Class B.—Infants who are given the breast in addition to the bottle undoubtedly have less tendency to diarrhœa and digestive disturbances. The average weight and the daily increase in weight are greater by far than in those cases which are fed on the bottle alone. The daily gain was greatest from the eighth to the twelfth and the twelfth to the sixteenth week, at a period when artificially fed children have the greatest difficulty in maintaining their weight. If we take thirteen cases in which the babies were given the breast and the bottle alternately, we note the following gain in weight:

8–12	12–16	16–20	20–24	24–28	28–32	32–36 week
30	24.8	12	19.5	13.7	9.2	11.2 per cent.

Koplik ascribes the irregularity in the gain to the tendency of mothers to overfeed their children, thus leading to dyspepsia and temporary losses. Nevertheless, the gain compared favorably with that given by Camerer in his table estimated from weighings of fifty-nine breast-fed infants.

Biedert, Meigs, and Rotch have devised methods by which we can imitate the natural food of the infant. Of these the

Meigs Mixture is unquestionably the best milk-modification that we have at present. It is a mistake to think that all we have to do is to recombine the elements of milk in the proportions present in mother's milk. Even with the method of Rotch, which allows all possible variations of the proteids, fat, and sugar percentages, there are a certain number of infants who will not thrive on any mixture we can devise. These are the cases in which atrophy gradually develops, and include those children who cannot digest milk in any form.

While some atrophic infants do not thrive on a fat percentage similar to that of mother's milk, in others the presence of the fat seems to favor digestion of the casein. This simply serves to show how complicated the problem of infant feeding really is. When we consider that in our great cities the majority of mothers have to depend on some form of home modification, the best of which are those formulated by Biedert, Meigs, and Heubner, we see that it is not so much the difference between 1.2 and one and a half or two per cent. proteids which decides the child's destiny as something inherent in the milk itself, in that we have to do with casein which is very indigestible, especially in the raw state.

Joseph C. Winters.[235] An artificial food must contain nothing that is not found in human milk; it must be of animal origin and it must be fresh. In metropolitan cities, where the milk reaches the consumer sixteen hours or more after milking, the proportions of the ingredients in the top milk will be fairly constant. Analyses made by Adriance of good milk as delivered in New York City show that the upper ounce from a quart of it will contain: fat 23.8 per cent., sugar 3.90 per cent., proteids 2.90 per cent.; the upper four ounces will contain: fat 21.8 per cent., sugar four per cent., proteids three per cent.; and the upper eight ounces will contain: fat seventeen per cent., sugar 4.3 per cent., proteids 3.1 per cent. Winters advises for the early days of infancy

no more than 0.25 per cent. proteids and no less than two per cent. fat. Infants so fed do not lose weight in the first week of life as they do under other conditions. An infant from three to four months old will not, as a rule, digest more than one per cent. of proteids in hot weather. At this time the proportion of lime-water should be increased to one-fourth of the total quantity used, and the strength of the food should be increased very gradually. Winters has seen scurvy follow the use of pasteurized milk, with rapid recovery on the use of the same food raw. He prefers, whenever possible, to employ milk which has not been heated.

Thompson S. Westcott.[254] This author believes with Rotch that milk-modifications should be prescribed in formulæ expressing the percentage composition of the different ingredients. For this purpose whole milk and creams of varying strengths are combined according to mathematical formulæ. He also gives a table showing the varying percentages of fat and proteids that can be obtained by mixing whey with cream of various fat percentages. In these estimations the amount of proteids is calculated according to König's analyses, which give 2.88 per cent. casein and 0.53 per cent. lactalbumin in cow's milk; the whey-proteids are estimated to equal 0.86 per cent. (see Chapter XIII.).

Westcott emphasizes the importance of maintaining the digestive equilibrium. For this purpose clinical experience has taught him that liberal amounts of milk and cream are needed. In mixtures containing from thirty to thirty-two ounces, for instance, the quantity of milk and cream must reach from twelve to thirteen ounces before satisfactory growth and nutrition can be expected. Dilutions weaker than this must be considered underfeeding. Both upon theoretical and clinical grounds, a percentage of proteids below 1.50 must be considered subnormal for any but the youngest infants; therefore, when low feeding must be maintained for a considerable time, this percentage should be kept constantly in mind as

the index of concentration which it is desirable to reach as soon as the strength of the infant's digestion will permit.

Westcott advises as a good working rule to make the fat percentage about three when the proteid percentage is one, and gradually to increase it to four, while the proteid percentage is increased to two. Exceptionally the fat percentage must be reduced below three for delicate infants or those of very tender age. For the purposes of modification:

	Fat. Per cent.	Proteids. Per cent.	Sugar. Per cent.	Salts. Per cent.
Whole milk is calculated to consist of...	4.00	4.00	4.40	0.70
Twelve per cent. cream is calculated to consist of..........................	12.00	3.80	4.20	0.64
Sixteen per cent. cream is calculated to consist of..........................	16.00	3.60	4.00	0.60
Twenty per cent. cream is calculated to consist of..........................	20.00	3.20	3.80	0.55

When it is necessary to reduce the proteids below one per cent. to establish digestive equilibrium, the use of the whey-proteids will enable the infant to appropriate a larger proportion of the more assimilable soluble albuminoids and perhaps a higher percentage of total proteids than any other plan of feeding. For this purpose, in preparing the whey, the curd, after forming, should be disturbed as little as possible, the whey being allowed to drain off entirely by gravity. The object of this is to obtain as low a percentage of fat as possible, since the mixture will now become essentially a cream dilution and nearly all the fat will be derived from the cream.

In a general way it may be said that in normal cases a proteid percentage of two should not be reached before the fifth or sixth month. In infants with chronic digestive disturbances it may be several months later before so high a percentage can be attained, and in cases of delicate digestion it may not

be possible to increase the percentage above two until near the end of the first year.

Since human milk contains from 6.5 to seven per cent. lactose, a corresponding percentage of sugar may be given in the mixture, except in the earliest days of life, when a percentage of 4.5, five, or 5.5 would be more suitable. Crystalline milk-sugar is to be preferred to the ordinary powdered sugar, which can readily be adulterated. It is preferable to add the necessary weight of sugar in dry form rather than to use a watery solution of definite percentage strength.

In cases of weak gastric or intestinal digestion in which only very low percentages of proteids can be assimilated, decided advantage is often gained by partial predigestion of the milk mixture. In this way, too, higher percentages of proteids can be given than is possible with simple dilutions. The author prefers to use peptogenic milk-powder for this purpose. Since this consists largely of milk-sugar, the bulk of the powder must be deducted from the quantity of milk-sugar added to bring the mixture to the desired percentage. The author has never observed the often-described ill effects of a partially peptonized diet, although this mode of preparation has been employed in many cases that demanded it for from three to six months or even longer.

It is usually best to discontinue partial predigestion slowly, first gradually reducing the time of action to three or four minutes, and then decreasing the quantity of powder to a third or fourth of the amount originally used, after which it may be omitted.

For clinical purposes Woodward's method of estimating the proteids in breast-milk and the Leffmann-Beam method for the estimation of fat are recommended (see Appendix).

Franklin W. White and Maynard Ladd [203] have recently called the attention of the profession to the subject of whey-cream modifications in infant feeding. They found, on referring to Bulletin 28 of the United States Department of

Agriculture, that a large number of specimens of whey, as purchased, yielded one per cent. of whey-proteids. König's analysis of whey, accepted by Westcott, allowed 0.86 per cent. for whey-proteids, and Westcott's formulæ were based on this figure. The result of six analyses by the authors confirmed the presence of one per cent. of proteids in whey. Several analyses of the total proteids in whole cow's milk gave 3.84 per cent.; of this, the average amount of whey-proteids was 0.90 per cent., or approximately one-quarter of the total proteids; the average amount of caseinogen was 2.94 per cent., or approximately three-quarters of the total proteids. They found that the best temperature for destroying the rennet enzyme in whey was 65° C. (149° F.). Temperatures of 69.3° C. and higher coagulate the whey-proteids. The rennet must be destroyed before mixing the whey with the cream, in order to prevent the coagulation of the cream by the enzyme.

By the use of thirty-two per cent. cream, fat-free milk, and a very concentrated solution of milk-sugar they were able to obtain whey-cream mixtures with a maximum of 0.90 per cent. of whey-proteids in combination with percentages of caseinogen varying from 0.25 to one, giving total proteids of from 1.15 to 1.90 per cent.

The emulsions of fat in whey, barley-water, gravity cream, and centrifugal cream mixtures were the same both in their macroscopic and microscopic appearances. The combination of heat and jolting during transportation, such as sometimes occurs in hot weather, partially destroys the emulsion in all forms of modified milk, but this disturbance can be prevented by the simple precaution of keeping the milk cool during delivery.

Whey-cream mixtures yield a much finer, less bulky, and more digestible coagulum than plain modified mixtures with the same total proteids; the coagulum is equalled in fineness only by that of barley mixtures. The coagulum yielded by gravity cream mixtures and centrifugal cream mixtures is the

same in character. The density of the coagulum is not affected by a variation of five per cent. in the fat content of the cream. Experiments on animals confirmed the results obtained in the test-tubes.

CHARLES W. TOWNSEND [145] emphasizes these practical points in infant feeding: that the child is not a machine, that children vary greatly in their digestive powers, and that they will not always do what is expected of them. Even with the most patient and intelligent changing of the formulæ to suit the varying needs of the case, laboratory modifications will not always agree, "though often of the greatest service." He thinks that a possible explanation lies in the fact that the cream separated by centrifugation recombines with milk, water, and lactose in varying proportions, and is then churned up by being carted around on the delivery wagon (see Maynard Ladd and White). He does not insist on pasteurization if the milk be: (1) fresh, (2) obtained from cows which are found to be free from tuberculosis by the tuberculin test, and (3) in no danger of contamination by the germs of typhoid fever or other infectious diseases. If there is doubt as to these three particulars, it is better to pasteurize at 156° F. for twenty minutes.

For home modification he recommends the use of top milk (upper fourth) which contains four per cent. proteids and from ten to eleven per cent. fat after standing from six to eight hours. His rule is: each ounce of ten per cent. cream in a twenty-ounce mixture represents .50 per cent. fat, .20 per cent. proteids, and .20 per cent. sugar. Each even tablespoonful of sugar of milk represents two per cent. The dilutions are made with lime-water and boiled water. Skimmed milk may be employed when it is desirable to increase the percentage of proteids. When using mixtures low in proteids, as in entero-colitis, the addition of white of egg is useful.

H. DWIGHT CHAPIN [25, 201] has recently recalled the attention of the profession to the use of top-milk mixtures in

infant feeding, and this subject will be discussed in Chapter XIII. He is also a prominent advocate of the use of decoctions of the cereals in infant feeding.[247] "The claim that cereal waters have no more effect on the curd of cow's milk than plain water has been abandoned, as it was based on the precipitation of casein with dilute acids and not upon its coagulation with rennet, which is what takes place in the infant's stomach. . . . To break up the curd of cow's milk and furnish a small quantity of easily absorbable food, cereal gruels, in which the starch has been converted into dextrin and maltose, are the most practicable and desirable agents. It is now admitted that cereals give the finest curd of any diluent, but it is claimed that the effect of the cereal is lost when the starch is digested, especially if the digestive ferment is active. How much effect a digested gruel has on the curdling of milk depends on the strength of the gruel and the dilution of the milk. The very best effect, so far as the digestive effort is concerned, is obtained when the starch is completely gotten into soluble forms, so that the particles of proteids and cellulose of the cereals are free." Experiments were made by adding rennet and 0.15 per cent. hydrochloric acid to (*a*) raw milk diluted equally with water, (*b*) the same diluted equally with one and a half per cent. starch jelly, and (*c*) the same diluted equally with dextrinized gruel. In *b* and *c* the curds were smaller and more flocculent than in *a;* in *b* the curds were coated with starch, but in *c* they were thoroughly exposed to the action of the gastric juice.

"It is not necessary to use a gruel stronger than one heaping tablespoonful of flour to the pint for any dilution of milk. Wheat, oatmeal, or barley may be used. Besides acting as mechanical attenuants, gruels possess some nutritive value, since they contain dextrin and maltose, which are readily absorbed."

A simple decoction of diastase may be made at home as follows. A tablespoonful of malted barley grains is put in

a cup and enough cold water added to cover it. This should be prepared in the evening and placed in the refrigerator overnight. In the morning the water is strained off and is ready for use. The diastases on the market or most of the thick malt extracts may also be employed. "Cereo," an active glycerite of diastase, is now especially made for dextrinizing gruels.

In cases in which the infant cannot take milk of any kind, Chapin has found the following to be of great use:

I. Dextrinized wheat gruel, eight ounces;
White of one egg (large);
Two even teaspoonfuls of granulated sugar.

This combination gives about two per cent. proteids and seven per cent. soluble carbohydrates.

II. Dextrinized wheat gruel, eight ounces;
Yolk of one egg (large);
Two even teaspoonfuls of granulated sugar.

This mixture will yield about 1.7 per cent. fat, 1.7 per cent. proteids, and seven per cent. soluble carbohydrates. The yolk also contains phosphorus and iron in organic combination.

LEEDS [133] expresses the following views with regard to the use of dextrinized attenuants. A gummy material like dextrin or a finely divided starch like that in oatmeal- or barley-water, along with more or less glutinous extractive matter, is much better adapted to serve as a mechanical attenuant of casein than farinaceous foods in their ordinary condition.

FLOYD M. CRANDALL [239] believes that the secret whereby the specialist may succeed in finding the proper proportions for an infant's diet more quickly than the practitioner of small experience is an open one,—namely, to begin on a weak mixture and work up to a point of tolerance. The average practitioner is afraid to dilute the milk sufficiently at the outset, and does precisely the opposite.

The three principal items to remember when writing for-

mulæ at the bedside are these: nine ounces of top milk contain twelve per cent. fat and four per cent. proteids; eleven ounces of top milk contain ten per cent. fat and four per cent. proteids; fifteen ounces of top milk contain eight per cent. fat and four per cent. proteids. The fact that one part of sugar to twenty parts of mixture will give a percentage of five is obvious.

By the simplest of calculations a great variety of formulæ can be arranged. The one source of error lies in the varying strengths of different milks, but this objection applies to every method of home modification.

Louis Fischer [171] calls attention to the fact that the natural food of an infant is neither boiled, sterilized, nor pasteurized, and believes that with the improved hygiene of the dairy it is safer to administer raw milk and thus avoid any risk of the development of scurvy. He agrees with the views expressed by Jacobi regarding the employment of modified Laboratory Milk. In his own experience, children fed on it were backward in development for a long time after its use. They always looked anæmic and their flesh was flabby, although their hygienic surroundings were of the best. He thinks that once the emulsion is destroyed by centrifugation or other mechanical process it cannot again become as homogeneous as before.

Ashby and Wright [2] recommend that milk should be prepared in the following manner. A thirty-ounce bottle is filled with fresh milk, plugged with cotton, and placed in an ice-chest or as cool a place as possible for five hours. The lower half is siphoned off and replaced with an equal quantity of seven per cent. lactose solution. This is sterilized at 160° F. for thirty minutes, cooled rapidly, and kept at a low temperature. The quantity to be given at each feeding must be heated to 100° F. before administering. With good milk this mixture will contain on the average 1.8 per cent. proteids, from three to three and a half per cent. fat, and six per cent. sugar.

For very young or delicate infants a weaker mixture may be made by siphoning off the lower two-thirds of the milk and adding five per cent. sugar solution. It is always well to render it alkaline by the addition of a few grains of sodium bicarbonate or a small quantity of a saturated solution of lime. We must not forget that milk is richer in winter, when the cows are stall-fed, than in spring, when they are at pasture. By increasing or diminishing the time of standing (five hours) we can increase or diminish the proportion of fat. For the poorer classes milk diluted only with lime-water or plain water must be used. At first two-thirds of the total quantity should consist of five per cent. sugar solution and one-twentieth lime-water. For a new-born baby it is undoubtedly best to begin with whey or diluted peptonized milk. After the first three or four weeks, if the digestion is good, equal parts of milk and sugar-water and one-tenth lime-water may be used. From three to six months give two-thirds milk and one-third sugar-water.

Whey may be given either alone, diluted with barley-water, or as a diluent for milk or cream. It is undoubtedly true that very many children are brought up on diluted cow's milk without cream and apparently thrive on it. Many such pass much curd in their stools without being the worse for it. The amount of food to be given depends partly on the age, partly on the powers of digestion of the infant and the degree of its development. It is as important to regulate the times for feeding and the amount as it is to decide on the nature of the food; neither age nor weight should be taken blindly as a guide to the amount of food that the infant should take.

At one month (weight from six to eight pounds) give from one to two ounces every two and a half hours. Eight bottles are required, with a total content of from twelve to fifteen ounces.

At two months (weight from eight to eleven pounds) give

from three to four ounces every two and a half hours. Eight bottles are needed, containing from twenty to thirty ounces in all.

From three to four months (weight from eleven to fourteen pounds) give from four to five ounces every three hours. Seven bottles are needed, containing from thirty to thirty-five ounces in all.

For the fifth and sixth months (weight from fourteen to sixteen pounds) give from six to seven ounces every three hours. Six bottles are needed, and the total quantity is from thirty-five to forty ounces.

Ashby believes that the addition of thin starchy fluids, such as barley- and oatmeal-water, after the third or fourth month checks rapid curdling of the milk and is of considerable value for the infant's nutrition. In some cases milk so diluted is better assimilated than when plain water is used. Under three to four months starch should be dextrinized.

Barley jelly, whole meal, maize, or oatmeal may be added to the diet at six or seven months, provided they are not in too concentrated solution to pass through the nipple. At seven months the child may have a crust to nibble on, but no other solid food, such as eggs.

Cautley [38] advises the following dilutions during the early months of life. The figures represent teaspoonfuls. Lime-water is to be added after boiling; if cream cannot be obtained, take an extra teaspoonful of top milk:

	First week.	Second week.	Third week.	Fourth week.
Milk	2	3	4	5
Cream	1	1	1	1
Water	5	6	7	8
Lime-water	1	1	1	1

One lump of sugar is to be added to each feeding.

	Two months.	Third to sixth month.	Sixth to ninth month.
Boiled cow's milk.	2 tablespoonfuls	3–4 tablespoonfuls	5–6 tablespoonfuls
Boiled water	2 tablespoonfuls	....	....
Barley-water	....	3–4 tablespoonfuls	5–6 tablespoonfuls
Cream........ ...	1 teaspoonful	....	1–4 teaspoonfuls
Lime-water	3 teaspoonfuls	....	... .

When cream cannot be obtained, cod-liver oil may be used instead after the sixth month. One lump of sugar is to be added to each of the mixtures.

Cautley believes that after the age of two months most infants can take milk diluted equally with water; in some cases it is necessary to still further dilute the milk (even seven or eight times), but by sufficient dilution at first any infant can become accustomed to take cow's milk. In his experience, cane-sugar can readily replace lactose without any ill effect, if given in the correct proportion. Milk-sugar ferments very much more readily than cane-sugar. When the milk-supply is adequate, starch should not be given to young infants (except in small quantities and in very weak solution) until the time of weaning. The appearance of six teeth may be considered an indication for its administration. Barley-water sometimes causes starchy indigestion. Stale bread, biscuit, crackers, and corn flour may be used towards the end of the first year.

Dextrinized attenuants act mechanically. Oatmeal contains more starch than barley-water and wheat more than either. The latter is therefore less easily acted on by the saliva.

Fenwick [52] advises the following mixtures for routine use during the first year of the infant's life.

First week:

Cream..........	2 teaspoonfuls	or	Cow's milk	1 tablespoonful
Whey	3 teaspoonfuls		Barley-water ...	1 tablespoonful
Lactose	10 grains		Lactose	15 grains
Water	3 teaspoonfuls			

From the second to the fourth week give each second hour from four A.M. to ten P.M.:

Cream .... 2 teaspoonfuls		or	Cow's milk .... 6 teaspoonfuls	
Cow's milk .... 1 tablespoonful			Barley-water ... 5 teaspoonfuls	
Lactose .... 15 grains			Lactose .... 15 grains	
Water .... 1 ounce				

For the third month give each two and a half hours from five A.M. to eleven P.M.:

Cream .... 3 teaspoonfuls	or	Cream .... 3 teaspoonfuls
Cow's milk .... 12 teaspoonfuls		Cow's milk .... 12 teaspoonfuls
Lactose .... 28 grains		Lactose .... 30 grains
Water .... 1 ounce		Barley-water ... 12 teaspoonfuls

For the fourth month give each two and a half hours from five A.M. to eleven P.M.:

Cream .... $3\frac{1}{2}$ teaspoonfuls	or	Cream .... 4 teaspoonfuls
Cow's milk .... 12 teaspoonfuls		Cow's milk .... 2 ounces
Lactose .... 40 grains		Lactose .... 45 grains
Water .... 2 ounces		Barley-water ... 2 ounces

For the fifth month give each three hours from five A.M. to eleven P.M.:

Cream .... 4 teaspoonfuls	or	Cream .... 5 teaspoonfuls
Cow's milk .... 2 ounces		Cow's milk .... 18 teaspoonfuls
Lactose .... 50 grains		Lactose .... 1 teaspoonful
Water .... $1\frac{1}{2}$ ounces		Barley-water ... 2 ounces

For the sixth month give each three hours from five A.M. to eleven P.M.:

Cream .... 4 teaspoonfuls	or	Cream .... 5 teaspoonfuls
Cow's milk .... 20 teaspoonfuls		Cow's milk .... 20 teaspoonfuls
Lactose .... 1 teaspoonful		Lactose .... 1 teaspoonful
Water .... 1 ounce		Barley-water ... $1\frac{1}{2}$ ounces

From six to twelve months the first meal should be at seven A.M.: one teacupful of dilute alkaline milk, humanized milk, or cream mixture. Second meal at 10.30 A.M.: milk as above, with a teaspoonful of malted food such as Mellin's Food, or bread jelly, or two teaspoonfuls of barley jelly. The third and fourth meals should be as above at two P.M. and six P.M. The last meal is to be given at 9.30 P.M. or ten P.M., and should be like the first. After seven months one teaspoonful of whole meal flour may be used instead of Mellin's Food, or a little fine oatmeal porridge may be allowed at the first meal. If indigestion follows or the infant ceases to gain, the food should be predigested with malt. After the ninth month the yolk of a soft-boiled egg may be given for the third meal, or a cup of veal, chicken, mutton, or beef broth with stale bread-crumbs.

Fenwick advises the use of lime-water in the milk in the proportion of one to twenty, to render it alkaline, and considers that barley-water is preferable to plain water as a mechanical diluent.

JOHN THOMSON [143] allows the healthy infant to take as much as it wants at regular hours of feeding. As a general rule, for the first six weeks of life he uses milk diluted with two or three times its bulk of water; from one and a half to four or five months, equal parts of milk and water; from the fifth to the eighth or ninth month, two parts of milk and one part of water, increasing after this until at the end of the year pure milk is given. In difficult cases he makes use of Frankland's, Meigs's, or Rotch's mixtures.

To neutralize the acidity, he recommends the use of lime-water in the proportion of one-sixth to one-eighth; sodium bicarbonate or magnesia may be used instead. The percentage of sugar should be brought up to normal by the addition of lactose or, if this is not obtainable, cane-sugar.

CHAPTER VI.

WEANING.

Authorities are nearly in accord as to the proper time to institute weaning. If the child is thriving and showing satisfactory gain in weight and development, breast-milk alone is sufficient until the ninth to the twelfth month (Starr, J. Lewis Smith, Williams, Cautley, Ashby and Wright, Thomson, Bendix, Monti, Gerhardt, Marfan, Taylor and Wells, Crozer Griffith, etc.).

Comby prefers to wean late (from the fifteenth to the eighteenth or twentieth month); he advises that the breast and the bottle should be given alternately. Marfan also thinks that it is advisable to keep the infant at the breast until the sixteenth month, but not after the eighteenth month, giving in addition artificial food. The breast-milk may prove a great resource in case of illness. A good indication for the administration of other food than that from the breast is the cutting of four teeth, showing that the development of the digestive tract is advancing.

On the other hand, Monti is inclined to believe that breast-feeding after the twelfth month is apt to result in malnutrition, anæmia, etc. Infants so fed may be fat, but will not necessarily be strong. Ashby expresses similar views. (These remarks seem to apply to infants fed solely at the breast.—Editors.)

Rarely it may be necessary to wean early—at the age of five or six months—if anomalies in the mother's milk develop or if the infant is not making satisfactory progress. In the latter case it is well to add artificial nourishment to the diet, but not to wean entirely until the necessary physiological development has taken place.[99]

The child should not be weaned during the hot months of the year, nor during or immediately after an illness, nor during a gastro-intestinal disturbance, unless this is due to a persistent faulty composition of the breast-milk.

Mixed Feeding.

Mixed feeding is preferable to insufficient nourishment from the breast, and is to be preferred to exclusive artificial feeding. The breast and bottle should be given alternately, and both breasts should be given at each nursing to maintain their secretion (Marfan). The value of mixed feeding is universally admitted.

Indications for Weaning.

MONTI.[99] I. Repeated profuse menstruation (during which the child loses weight on account of changes in the composition of the milk).

II. Pregnancy (requires immediate weaning).

III. Acute infectious febrile disorders (unless of very short duration).

IV. Failure of the child to thrive.

(The last indication calls for mixed feeding rather than for absolute weaning, unless careful analysis of the mother's milk shows that it is entirely unsuited to the needs of the infant.—EDITORS.)

Opinions differ as to the effects of menstruation and pregnancy on the secretion of the breasts. Marfan thinks that under ordinary circumstances the return of the menses does not necessitate weaning, unless marked digestive disturbances occur and the child ceases to gain for a certain length of time. Pregnancy is not incompatible with nursing; if the mother is strong and healthy, she can nurse her child until the latter months of gestation. The mother's condition and the amount of milk she secretes must decide the question (Bendix).

COMBY[62] considers that the return of the menses should

never demand immediate weaning. There may be some temporary disturbance, but one should not on this account wean prematurely.

Bendix,[226] from the careful study of one hundred and forty cases, concludes that the mere occurrence of menstruation is insufficient ground for weaning, even when alterations take place in the quality and quantity of the milk, since these changes are of a temporary character only and will not seriously affect the child's condition. He also considers that the infectious fevers are not a contraindication to nursing. In one case of measles, one of scarlet fever, and one of influenza the mothers were able to nurse their babies throughout the diseases and the infants remained healthy (except for a slight dyspeptic attack in the latter case). Tuberculosis is of course a positive contraindication to nursing.

Taylor and Wells [147] think that, as a general rule, it is best to wean on the diagnosis of pregnancy being established, since this disturbs the equilibrium of the milk secretion. Usually, too, the continuance of menstruation affects the composition of the milk to a marked degree. According to Rotch, there is a decided increase in the proteids and a diminution in the fat. By emptying the breasts with a pump these periods may be tided over and the necessity to wean may be averted.

Holt.[183] It is important that the physician should be familiar with the symptoms of inadequate nursing. During the first days of life an important sign is a rise of temperature to 101° or 102° F., or higher, without obvious signs of illness.

Symptoms of inadequate nursing may be grouped as follows: colic, fretfulness, loss of sleep, with either no gain in weight or a loss of several ounces a week, and abnormal stools. All of these, persisting beyond the third or fourth week of the mother's convalescence, justify immediate weaning.

"Since artificial feeding, when properly carried out, gives so much better results than poor or doubtful nursing, it is

better to stop nursing after a fair trial—*i.e.,* two weeks—has been made rather than waste time in prolonged efforts to improve the breast-milk."

Method of Weaning.

All authorities are agreed that it is advisable to wean gradually; the time required for gradual weaning is from two to five weeks. For instance, Monti says to give one extra meal a day for one week, two a day during the next week, three a day during the third week, and so on. At the end of four or five weeks cease nursing altogether.

Undoubtedly the best food with which to wean a child is properly prepared cow's milk. The child has to learn to digest cow's milk casein just as in the early months of life, but with much greater probability of success. It is safer, therefore, to begin with a high dilution of cow's milk, such as one part of milk to two parts of water, with the addition of cream if desired. If this agrees, the strength of the mixture can rapidly be increased until at the end of two weeks equal parts of milk and water and at the end of one month three parts of milk to one of water or whole cow's milk may be given. If weaning is carried out before the tenth month, a longer time may be necessary, and for infants of weak digestion higher dilutions or special mixtures may be required. In preparing the milk mixture for weaning it will usually be found advantageous to use a starchy decoction, such as barley-water, for our diluent instead of plain water, or to add one of the reliable infant foods. This addition of starch is indicated not only to render the milk more digestible, but also to increase the proportion of carbohydrates. Holt's rules (see page 139) for the feeding of difficult cases during the second year hold good for any case in which the digestion of cow's milk offers special difficulty. Again, many children do well on milk mixtures, but suffer from repeated attacks of indigestion following the administration of solid food. Starches in concentrated

form, such as cakes, bread, potatoes, oatmeal, etc., will generally be found to be the articles at fault; their withdrawal and the substitution of milk and broths will usually be followed by complete recovery. The common practice of giving the infant a "taste" of tea, coffee, or alcoholic beverages need only be mentioned to be condemned. Under the following headings we have included those articles of food which may form the child's diet from the time of weaning until the end of the second year. Experience has shown that infants do best on plain food. Once the child has acquired a taste for sweets and highly seasoned articles of food it will rarely be satisfied without them; therefore it is much kinder to withhold such articles absolutely until a later period of life.

Starches.

After the ninth month starches may be given to healthy infants, and sometimes earlier, provided five or six incisors have appeared and there is an abundance of saliva present. The best preparations of starch are thoroughly cooked gruels or jellies and the infant foods, preferably those which are dextrinized or malted; "Infant's Zwieback" may also be recommended. If one of the infant foods is selected, begin by adding one teaspoonful to the milk mixture once or twice a day, increasing gradually to a tablespoonful at each feeding, if it is well tolerated. When the child is one year of age we may add stale bread-crumbs to the diet once or twice a day mixed with the milk or with meat broth; or the child may be given a hard crust of bread to chew. If signs of indigestion supervene, we must immediately reduce the amount of starchy food; it may be necessary to cut it off altogether if the digestive disturbance is marked. Some children cannot digest starch until the end of their second year. Fermentation of starchy food causes colic and diarrhœa, but seldom gives rise to marked constitutional disturbance, in contradistinction to the enteritis following "milk infection."

Meat Broths.

Mutton, veal, chicken, or beef broth may be given to the child when he is one year old. Their use is indicated before this time if the child has rickets or gastro-intestinal disturbances. One cupful (from six to eight ounces) of broth with the fat carefully removed may take the place of a milk feeding in the middle of the day. The broth may be thickened with a starchy gruel, or its nutritive value increased by the addition of the yolk of an egg (during the second year), or cream may be added to it for infants with weak digestions.

Raw Beef Juice.

This is one of the most assimilable forms of albuminoid food. It can be given with safety to an infant over one year of age in doses of from half an ounce to an ounce. From one to three ounces may be given during the twenty-four hours. The administration of beef juice to infants under one year may be desirable in cases of rickets, scurvy, malnutrition, etc. One teaspoonful may be given once or twice a day to a child nine months old.

Scraped Meat (Beef or Mutton).

This can form part of the healthy child's diet during the second half of the second year. Rotch prefers not to begin its administration until the first half of the third year. One tablespoonful may be given once a day at the midday meal, to take the place of the beef juice. It should not be given to infants with weak digestion. Cautley allows white meat of chicken at this period.

Yolk of Egg.

This can be added to a pint of meat broth or to a starchy gruel. It is a convenient means of adding fat to the diet, but we must remember that it is not as easily assimilated as good

cream. Since the yolk of one egg contains thirty-two per cent. fat (König), it must be well diluted to render it digestible. A vigorous, healthy infant may be given the yolk of egg at the age of nine or ten months, but in the majority of cases it is well to wait until the child is from twelve to eighteen months old before making this addition to the diet. A soft-boiled egg may be given once or twice a week after the sixteenth month. Cautley allows custard at this age.

Bread and Butter.

A small slice of stale bread, plain or toasted and thinly buttered, is permissible after the first year, and may form part of the daily diet. Rye, Graham, or whole wheat bread may be used if the child is constipated.

Rice, Potato, Hominy, etc.

One large tablespoonful of well-boiled rice or hominy, mixed with milk, may be given to a healthy child for its dinner two or three times a week during the latter half of the second year. In place of it, the child may have one tablespoonful of thoroughly baked well-mashed potato, with a little butter and salt. Beef gravy may take the place of the butter. Monti allows purée of peas.

Green Vegetables.

A small quantity of well-boiled spinach is allowed now and then by Monti and Cautley after the eighteenth month. Fenwick gives occasionally a little stewed celery, well-cooked asparagus tips, or cauliflower.

Dessert.

One or two tablespoonfuls of junket, custard, or plain rice and milk pudding may be given with the dinner to a healthy child during the second year. Cautley allows farina, and Fenwick sago and tapioca pudding.

Fruit.

Orange juice is a valuable addition to the child's diet and possesses antiscorbutic properties. It may be given in teaspoonful doses, increased to one or two ounces at the end of the first year. Apple sauce, the soft part of two or three stewed prunes, or a slice of baked apple is admissible during the latter half of the second year. Rotch allows a ripe peach at this age.

Holt.[183] Milk should be the basis of the diet during the second year of life. The child should be weaned from the bottle by the thirteenth to the fifteenth month, except perhaps the night feeding. For the average case little modification of the milk is necessary unless it be very rich, when it should be diluted one-fourth or more, during the hot weather especially. If the milk is poor in fat, use the upper two-thirds of the bottle.

Farinaceous gruels may advantageously be added to the milk mixtures. The total quantity of liquid food to be given during the first six months of the second year should be from forty to fifty ounces a day; during the last six months this quantity should be increased to forty-five or fifty-five ounces.

D. J. Milton Miller[100] advises that the diet in the second year should be largely nitrogenous with a minimum of carbohydrates, the latter to be given in the form of gruels or jellies. Bread must not be used before the end of the second year, unless crushed and mixed with milk; it must be well dried in the oven, or we may use zwieback instead. Of course many children can digest farinacea well during the second year; to insure the best results, however, we must be cautious in the administration of starchy foods, which are such a frequent cause of indigestion during the second and third years of the child's life.

Jacobi.[76] Beef and meat broths may be given towards the

end of the first year, or at any time in rickets; mutton broth should be used if there is a tendency to diarrhœa. Beef tea contains much salt, and hence it is dangerous to give it in summer diarrhœa; it is low in albuminoids, and may be rendered more nutritious by the addition of farinacea or egg albumin. Beef broth is about as rich in albuminoids as whey; it contains extractives, creatin, and creatinin. It should not be given when there is gastric irritation, gastritis, or acute dysentery. Veal broth is liable to increase diarrhœa and mutton broth to increase constipation.

Peptonized beef preparations are valuable, but the condition of the digestive organs must be carefully considered. The last product of gastric digestion is albumose. The formation of peptone is not completed till the action of the pancreatic ferments and perhaps certain intestinal bacteria has manifested itself. Peptone can be formed without the presence of hydrochloric acid. Scraped raw beef is easy of digestion; it is of use in the chronic stage of, and during convalescence from, gastro-intestinal catarrh.

White meat, such as chicken, contains less fat, hæmoglobin, and extractives than beef. The white of egg alone may be valuable for temporary use, or it may be given as a permanent addition to other food.

J. Rudisch has devised the following method of preparing milk for infants with gastric catarrh or who cannot digest milk in its usual form. He mixes from twenty-five to thirty minims of dilute hydrochloric acid with a pint of water, adds a quart of milk, and boils for a few moments. This preparation keeps well, is palatable, and highly digestible. Bunker has recently called attention to this method.

Somatose is worthy a trial because it does not contain those nucleins which irritate the kidneys and because it is a genuine albumose: one teaspoonful contains as much albumin as half an egg or three tablespoonfuls of milk.

The artificial farinaceous foods, in which starch is more or

less transformed into dextrin, fill a gap for those rare cases in which milk, though ever so well prepared, or the cereals, such as oatmeal and barley, are not well tolerated.

Extract of malt contains albuminoids, fifty-three per cent. of sugar, and fifteen per cent. of dextrin; one tablespoonful of it is equivalent in nutritive value to one egg. It may be serviceable; it is very nutritious on account of its richness in sugar, and should be utilized oftener than seems to be usual.

Monti [99] states that cereal coffee may be used as an addition to the milk in cases in which the digestion is poor (rickets, scrofula, etc.), and likewise cocoa. Neither contains enough fat or albumin to be of much nutritive value. Tea and coffee, especially black coffee, are useful stimulants for collapse and heart weakness in infants; in fact, in many cases they are preferable to alcohol. After the eighteenth month a small amount may be added to the milk without hurting the child and with no danger to the nervous system (? Editors).

Alcohol is not needed normally. Used judiciously, it has decided value in furthering digestion in weak, sickly, and anæmic children. Brandy, wines (with a low percentage of alcohol), and beer may be used.

Water should be given with each meal (from five to seven ounces at least).

For purposes of comparison as well as clearness, we have tabulated the diet lists (during the second nutritive period) of Fenwick, Starr, and Cautley.

Diet for the Second Nutritive Period (Twelve to Eighteen Months).

First Meal from Six to Eight A.M.

Starr.[133] A slice of stale bread soaked in a cup of fresh milk, or the lightly boiled yolk of one egg with bread-crumbs and milk.

FENWICK.[52] From eight to ten ounces of milk with a slice of thin bread and butter or rusk, or milk and a teaspoonful of Quaker oats.

Second Meal from Nine to 10.30 A.M.

STARR. Six ounces of milk with a thin slice of buttered bread or a soda biscuit.

CAUTLEY.[38] A bowl of thick gruel or oatmeal porridge, or a cup of cocoa and milk with bread and butter.

FENWICK. Milk and rusk or plain biscuit.

Third Meal from One to Two P.M.

STARR. A cup of meat broth with a slice of bread and one tablespoonful of rice and milk pudding, or a mashed baked potato moistened with one or two ounces of beef tea, and two tablespoonfuls of junket.

FENWICK. Tapioca or sago pudding may be used instead of the rice pudding, and a little stewed fruit may be given once or twice a week.

CAUTLEY. The lightly boiled yolk of an egg or a poached egg with stale bread; stale bread-crumbs in beef tea, soup, or broth, and a large tablespoonful of custard, corn flour, or blanc-mange.

Fourth Meal from Five to Six P.M.

Same as the first or second.

Fifth Meal from Nine to Ten P.M.

STARR. Half an ounce of Mellin's Food with half a pint of milk.

CAUTLEY. A cup of milk gruel made with rice, tapioca, sago, or hominy; or rusk or lady-finger.

In Starr's opinion, the fifth meal is often unnecessary and the child should never be wakened for it. If the child wakes early in the morning, it should be given a cup of warm milk.

DIET FOR THE SECOND NUTRITIVE PERIOD (EIGHTEEN MONTHS TO TWO YEARS).

First Meal from Seven to 7.30 A.M.

STARR. Half a pint of fresh milk, the yolk of an egg, and two slices of bread and butter.

CAUTLEY. One ounce of well-cooked oatmeal or wheaten grits with sugar and cream, and a glass of milk.

Second Meal from 10.30 to Eleven A.M.

STARR. Milk and bread and butter or a soda biscuit.

FENWICK. In addition to the above, treacle, sugar, or marmalade.

Third Meal from 1.30 to Two P.M.

STARR. Eight ounces of beef, mutton, or chicken broth with a slice of stale bread and butter and a saucer of rice and milk pudding; or half an ounce of underdone mutton pounded to a paste, and a mashed baked potato moistened with dish gravy and a saucer of junket.

FENWICK. Custard, tapioca, or rice pudding; finely minced mutton-chop or a boiled egg; stewed celery, well-cooked asparagus, or cauliflower may be given occasionally with dinner. When the first set of molars are cut, a small amount of boiled sole or cod or finely minced boiled fowl may be given.

CAUTLEY allows spinach, and ASHBY and WRIGHT [2] stewed apples and preserves.

Fourth Meal at 6.30 P.M.

STARR. A cup of milk with bread and butter, or toast, or milk toast.

FENWICK. The yolk of an egg lightly boiled, or cocoatina (half a drachm to six ounces of milk), or treacle.

CHAPTER VII.

CARE OF THE MILK.

It is scarcely necessary to describe in detail the numerous ways in which milk may become contaminated during the process of milking. To those who are not familiar with the conditions at the average dairy farm, it is evident that when the udder and teats of the cow are not washed, and the hands of the milkers, the milk-pails, and utensils only hastily and imperfectly cleansed, the opportunities for milk infection are manifold.

It is interesting to follow such milk from the time when it is drawn until it reaches the consumer; unfortunately, much the larger portion of the city's supply meets with the following treatment. The milk drawn in the morning, after being aërated by pouring from can to can, is taken from the various farms to the nearest railroad station, where it stands in its forty-gallon cans until removed to the distributing stations in the city. From these the various small milk dealers remove it as soon as feasible to their dairies. During this time no attempt has been made to keep the milk cool other than the use of a protector over each can in the wagon.

With the morning's milk is also sent the milk of the previous evening, which has been kept cool (probably from 50° to 54° F.) through the night. When the dairy supply is at a great distance from the city, the morning's milk is not sent to town until the following morning, it being then twenty-four hours old.

As before said, the various small dealers remove their consignments at once to their dairies, and from this time some of this grade of milk receives fair treatment, being at once cooled in ice-water and perhaps bottled, ready for delivery.

In the hands of less careful dealers, however, many further accidents befall it.

The main delivery is made in the morning following the arrival of the milk in town, when it is from twenty-four to forty-eight hours old; during hot weather an extra delivery is made at noon. As might be expected, in summer weather such a product will necessarily become sour soon after delivery, and the temptation for the small dealer to use preservatives is in many instances too great to be resisted.

The milk is delivered either in the can or in bottles. Unfortunately, the practice of ladling the milk from the can on the "route" is still very prevalent, and it is easy to imagine the many additional means for its contamination during this process. The use of bottled milk is becoming more popular, however, and if the milk were only pure to begin with, many of the dealers could be trusted to fulfil fair requirements of cleanliness in distributing it. The practice of filling bottles on the wagon, although not the rule, is unfortunately quite common. The demand for bottled milk on a particular route may exceed the supply, and nothing is easier than to fill some of the bottles, returned by patrons, from the can, with no further precautions for the cleanliness of the bottles than the housewife has chosen to take!

It is needless to comment on such a practice, which has probably given rise to the principal objection made against bottled milk,—namely, the danger of contagion conveyed by the bottle. If the bottles are not thoroughly scalded and cleansed before refilling, they may thus prove to be even more dangerous than the large delivery can.

The use of coloring matter and cream thickener is very general. They do less harm, perhaps, than preservatives, unless they are added to an ordinary milk and sold for cream, thereby cheating the customer out of his rightful fat percentage. Annotto, a vegetable product, is the principal form of coloring matter used, and a compound of powdered gelatin and boric

acid, such as Heller's Cream Albumin, gives to "cream" its richness and consistency.

From this short account it will readily be seen how many are the defects and how serious may be the dangers of the city milk-supply. In marked contrast to the ordinary supply of milk is that sold under the seal of the various milk commissions which have been established in many of the larger cities.

Before describing certified milk, however, it will be well to give a small part of the overwhelming evidence as to the extent to which milk may be contaminated with disease-producing micro-organisms.

Estes [246] examined one hundred and eighty-six specimens of milk coming from all parts of England. The bacillus tuberculosis was present in eleven cases (5.3 per cent.), doubtful in two cases. Pus was present in forty-seven cases (thirty per cent.), muco-pus in seventy-seven others (48.7 per cent.). Blood was present in twenty-four specimens; streptococci in seventy-five per cent. of all the cases. Eighty per cent. of all the samples contained pus, muco-pus, or streptococci, and were unfit for use.

Additional instances of contamination with bacteria will be found in Chapter VIII.

William R. Stokes and G. Wegefarth,[245] investigating the microscopic appearance of milk, find that the occurrence of garget or inflammation of the udder in cows is not infrequent, and that milk from such animals contains many pus-cells and organisms of suppuration. The studies of Booker and others strongly suggest that such milk can cause various forms of gastro-enteritis.

The microscopic examination of milk will often draw attention to a condition which might otherwise escape notice. The authors carried out three series of investigations:

(1) One hundred cows in the country under improved hygienic care.

(2) Fifty cows in the country under poor hygienic care.

(3) One hundred cows in the city, stall-fed and under poor hygienic care.

The milk from Series No. 1 gave an average of 1.1 pus-cells to the microscopic field (one-twelfth objective) and practically no pus organisms.

That from No. 2 gave an average of 11.3 pus-cells, and that from No. 3 gave an average of 19.2 pus-cells, while strepto-cocci were present in large numbers.

The authors conclude that when pus-cells are found in large numbers in milk it should suggest a careful inspection of the herd. The standard for exclusion must necessarily be arbitrary, but an average of more than five pus-cells to the field with a one-twelfth oil immersion objective should exclude an animal from the herd.

R. G. Freeman [179] in a recent article discusses briefly the diseases which can be transmitted in milk and the best means to avoid contamination. He classifies such diseases as follows:

I. Those in which the pathogenic germs that are introduced into the milk are conveyed from the body of the diseased cow, as tuberculosis, anthrax, foot-and-mouth disease, and acute enteritis.

II. Those in which germs gain entrance from some other source either during or after milking, such as cholera, typhoid fever, scarlet fever, and diphtheria.

III. Those caused by milk which contains poisonous agents developed by bacterial growth.

In all these diseases, except anthrax, we have very conclusive evidence that the milk-supply may be the source of contagion. From the study of epidemies so caused Freeman draws the following lessons:

I. Whenever a case of communicable infectious disease is reported, inquiry into the source of the milk-supply should be made.

II. Milk traffic should be carried on in houses separate from the dwelling-house; the dairy building should be at least one hundred feet from the dwelling-house, barn, or privy. It should be on a higher level of ground than any of these, and should have its own pure water-supply. All of the work of the dairy should be done in this dairy building, including the cleansing of the pails and cans.

III. It should be unlawful for any one who has come in contact with a sick person (when the sickness is not positively known to be non-contagious) to enter the dairy building or barn or to handle the milk.

IV. All employees connected with the milk traffic should be compelled to notify the authorities on the outbreak of any disease in their abodes, and to abstain from work until permission to resume is granted them by the authorities so notified.

V. Cities should accept milk only from those dairies which are regularly inspected and where all the cows have been tested with tuberculin, and where those which give the characteristic reaction have been killed and the premises disinfected.

VI. The tuberculin test should be applied to all cattle, and those which react should be killed, the owner being reimbursed from State funds. The premises on which such tuberculous cattle have been kept should be thoroughly disinfected. All cattle which are brought into a State should be quarantined until the tuberculin test has been applied.

VII. The use of one long trough for the purpose of feeding many cattle should be avoided, since it is a ready means for the conveyance of pathogenic germs from one animal to another.

Undoubtedly, the adoption of such regulations would do much to reduce the amount of sickness conveyed by germs in milk. Freeman does not think that any regulations can entirely eliminate this danger. He concludes, therefore, with a word of caution in favor of the destruction of pathogenic germs by some process of sterilization.

In this country steps have been taken in several of the large cities to provide a milk which shall come up to recognized standards of strength and purity. The pioneer attempts to thus standardize the milk-supply were made by Henry L. Coit, of Newark, New Jersey.

Milk Commissions, consisting of three or more pediatrists, now exist in New York, Philadelphia, Baltimore, Boston, and Buffalo.

The Commission of the Philadelphia Pediatric Society has established the following requirements:

. . . .

"7. The Commission shall select a bacteriologist, a chemist, and a veterinary inspector. The bacteriologist shall procure a specimen of milk from the dairy or preferably from delivery wagons, at intervals to be arranged between the Commission and the dairy, but in no case at a longer interval than one month. The exact time of the procuring shall be without previous notice to the dairy. He shall test this milk for the number and nature of bacteria present in it, to the extent which the needs of safe milk demand. He shall also make a microscopic examination of the milk for pus-cells. Milk free from pus and injurious germs and not having more than ten thousand germs of any kind or kinds to the cubic centimetre shall be considered to be up to the required standard of purity.

"8. The chemist shall in a similar manner procure and examine the milk for the percentage of proteids, fat, sugar, mineral matter, and water present. He shall also test its chemical reaction and specific gravity, and shall examine it for the presence of foreign coloring or other matters or chemicals added as preservatives. Standard milk shall range from 1029 to 1034 specific gravity, be neutral or very faintly acid in reaction, contain not less than from 3.5 to 4.5 per cent. proteids, from four to five per cent. sugar, and not less than from 3.5 to 4.5 per cent. fat, and shall be free from all foreign contaminating matter and from all addition of chemical substances

or coloring matters. Richness of cream in fat shall be specified, and shall vary not more than one per cent. above or below the figures named in selling. Neither milk nor cream shall have been subjected to heat before the examination has been made, nor at any time unless so announced to the consumer.

"9. The veterinary inspector shall, at intervals equal to those of the bacteriologist and chemist, and without previous warning to the dairy, inspect the cleanliness of the dairy in general, the care and cleanliness observed in milking, the care of the various utensils employed, the nature and quality of the food used, and all other matters of a hygienic nature bearing upon the health of the cows and the cleanliness of the milk, including also, as far as possible, an inquiry into the health of the employees on their farms. He shall also see that the cows are free from tuberculosis and other disease.

"10. . . . Any dairy, the milk of which shall be found by the examiners to be up to the standard of the Commission, shall receive a certificate from the Commission.

"11. In case an examination shows the milk not up to the standard, the dairy may have a re-examination made within a week or within a short time, at the discretion of the Commission.

. . . .

"13. The dealers to whom certificates have been issued shall furnish milk to their customers in glass bottles, hermetically sealed in a manner satisfactory to the Commission. In addition to the sealing, and as a guarantee to the consumer that the examination has been regularly conducted, there shall be pasted over the mouth of the jar, or handed to the consumer with every jar, according to the discretion of the Commission, a certificate slip. . . ."

The inspection and analysis of certified milk are most thorough, since not only the hygienic cleanliness of the milk but also the percentage of its ingredients must be determined.

To insure a uniform standard in the constituents of milk, careful selection of the cattle is required and an equal care in their feeding and daily hygiene. The best breeds of cows available for infant feeding in this country, according to Rotch,[119] are the Durham, Devon, Holstein-Friesian, Ayrshire, Bretonne, and Brown Swiss. The red cows in this country do not come up to the standard, owing to their liability to gastro-intestinal disorders. The famous Jersey and Guernsey cows furnish a rich milk, but they are more liable to contract tuberculosis (when trausported from the Channel Islands to a more severe climate) than the breeds above mentioned. Some dairies require a two months' quarantine for Jersey and Guernsey cows before applying the tuberculin test.

Rotch [119] declares that cows which furnish milk for infant feeding should possess the following characteristics:

I. Constitutional vigor.

II. Adaptability to acclimatization.

III. Notable ability to raise their young.

IV. Freedom from intense in-breeding.

V. Distinct emulsification of the fat in the milk.

VI. A preponderance in the fats of the fixed over the volatile glycerides.

Volatile glycerides do not exist in the mammæ, but form in the milk soon after milking, especially in the case of Jersey and Guernsey cows.

Cautley.[38] The failure of cow's milk to give satisfaction as an artificial food may be due to one or more of the following conditions:

I. A faulty condition of the cow, such as excessive age, prolonged lactation, recent calving (the milk containing colostrum corpuscles), etc.

II. Diseases of the cow, such as pneumonia, foot-and-mouth disease, diseases of the udder, etc.

III. Improper feeding and care of the animal.

IV. Improper or careless milking.

V. Improper handling of the milk before it reaches the consumer.

VI. Improper composition of the milk, such as deficiency in fat, etc.

MONTI[99] says: "To get proper milk of stable composition the cow should have calved three months previously, and only the milk obtained during the next four months should be used; after this the milk contains too much casein and too little sugar and fat."

TAYLOR and WELLS[147] give the third to the ninth year of the cow's life as the best period of lactation.

KLIMMER[85] states that the liability to tuberculosis increases with the age of the cow, and that tuberculosis is especially prevalent during the best years of lactation.

Milk should not be used until free from colostrum corpuscles, nor during advanced gestation. During the catamenia it is probably unfit for infant feeding, but this objection scarcely applies if the mixed milk of the herd is used.

The next most important factors for the production of clean milk are the care of the cow and cleanliness in the process of milking.

ROTCH says that the barn should have a capacity of at least twelve hundred cubic feet of air for each cow; light and ventilation are essential, especially in the prevention of tuberculosis. Whenever the weather permits, the cows should be turned out in the sunning yards when not being milked. These yards should drain away from the barn, the water-supply, and the milk-house. The fittings, troughs, floor, etc., of the barn should be of impervious material capable of being thoroughly cleansed with water; the floor should drain well to remove excreta. The stall should be wide enough to allow freedom of motion for the cow. The bedding should be fresh and free from mould or any soil productive of bacterial growth. At the Walker-Gordon farm at Chestnut Hill, Pennsylvania, they find that shavings answer the purpose admirably. Whatever the

material selected, it should be changed before milking,—twice a day.

The cows should be treated with a proper amount of consideration, especially before the milking hours. Fright and unusual excitement must be avoided, as they are apt to disturb lactation or may even suppress it. The water-supply for the herd must be above suspicion; it is best that each cow have a separate drinking-trough in which the water can be renewed frequently.

One part nitrogenous to five and a half or six parts non-nitrogenous is the proper ratio in the cow's fodder to produce the milk best suited for the infant's needs. The nitrogenous elements are found in clovers, beans, peas, vetches, wheat bran, etc., while timothy, rye, Kentucky-blue, maize meal, and oat straw represent the non-nitrogenous. In the green state most of the grasses afford a fairly balanced nutriment, but care must be exercised in changing from fresh to dry rations, owing to the changes which this causes in the composition of the milk, thereby interfering with its proper digestion.[119]

Plenty of food and little exercise increase the yield of milk.[38] Nitrogenous foods increase the fat [38] and the caseinogen.[52] Carrots and beet roots increase the sugar of milk.[52] The refuse from breweries and distilleries makes milk abundant in quantity but deficient in solids. Diseased potatoes or turnips give an unpleasant taste and smell.[52]

Cautley considers that, on the whole, pasture-fed cows are apt to produce a milk better suited for the infant than that of stall-fed animals. Grass-fed cows are apt to have alkaline or nearly alkaline milk. Those fed in stalls on dry fodder and grain usually give milk of an acid reaction.[119]

Gordon has found that Austrian sugar-beets, in the proportion of ten pounds daily per cow, as part of the non-nitrogenous element of the diet, made the milk neutral or slightly alkaline. This reaction persisted for several hours at

the ordinary temperature. One-third of the milk from the cows so fed, when added to two-thirds of the mixed milk of a herd fed on ordinary diet, caused a neutral or slightly alkaline reaction.[119]

In order to obtain milk in an approximately sterile condition several things are necessary. The cow's udder, abdomen, flanks, and groins should be well groomed, and during the hot weather the hair should be clipped. In addition to this, before each milking, they should be thoroughly washed, preferably with a 1 to 1000 bichloride solution, and carefully dried. This process should include the teats as well. During the summer time particles of dirt fall into the milk-pail from the switching of the cow's tail in driving off the flies. Care should therefore be taken to prevent as far as possible the entrance of flies into the barn, and by the use of narrow-mouthed milk-pails to avoid contamination from the air and the sides of the cow.

The milkers should be dressed in clean sterile white suits and caps. Their hands and arms should be thoroughly scrubbed and dried before each milking; in some dairies the use of sterilized cotton gloves is advocated. No one suffering from, or who comes in contact with, any infectious disease should be allowed to perform any duties in connection with the dairy farm.

In the milking process sufficient force should be exerted to imitate suction by the calf, and at each milking every drop should be withdrawn. The first few drops or streams should always be discarded, so that the milk-ducts may be washed free from bacteria.

The milk-pails may be of a variety of designs, but a long, narrow pail offering a small surface for air contamination, and with rounded corners and edges to insure easy and complete cleansing, embodies all the essentials. As soon as the pail is filled it should be carried to the milk-house.

The following is a description of the milk-house at the Walker-Gordon farm near Philadelphia.

The milk-house is situated far enough from the barn to be free from all odors. Its construction insures thorough ventilation; the windows and doors are all protected with fly-screens. The milk-house is divided into three rooms,—the engine-room, the washing- and sterilizing-room, and the milk-room proper. The floors are of concrete to allow of flushing.

The milk-cans, when filled, are brought from the barn and emptied into a covered receptacle set in the wall of the milk-room. This is further protected from the air and dust by a shed; in this shed are also steam faucets over which the cans are inverted and filled with live steam before using again. The milk runs from this receptacle through a pipe in the wall of the milk-room directly to the aërator and cooler, and is strained through eight thicknesses of sterile gauze on the way. This obviates the necessity for the milkers to have access to the milk-room.

The milk runs down from the pipe over a corrugated zinc plate which is cooled by a set of ice-water tubes under it, and then drops into a porcelain tub, from which it can be drawn off and bottled. This aërating process reduces the temperature to about 60° F. The milk is then bottled, sealed with sterile pasteboard caps, placed in ice-water, and kept at a temperature of from 45° to 50° F. until ready for delivery. During the heated term the bottles are packed in cracked ice before being placed in the wagon.

A portion of the milk-supply of the Walker-Gordon plant, instead of being bottled, is run through the separator and the cream shipped to town for use in the Milk-Laboratory. The morning's milk can be delivered within eight hours of being drawn, the evening's product never arriving later than from twelve to eighteen hours after milking.

When the bottles are returned from the consumers they are thoroughly washed in water containing soda and are then sterilized with live steam for thirty minutes. The porcelain tub into which the milk falls from the aërator can also be cov-

ered and sterilized with steam. By these means all possible chances for contamination are rigorously excluded.

The experiments of Peters [119] seem to prove that a practically sterile milk can be obtained, provided the proper precautions are carried out. Four cows were used in these experiments. The milker was dressed in a sterilized white suit and cap, and his hands and arms thoroughly washed with a 1 to 1000 bichloride solution. The cows' udders, teats, flanks, sides, and abdomens were washed with the same solution and dried with a sterile towel, and the milk was received in sterile bottles.

	No. of colonies of bacteria per cubic centimetre.
No. I. Milk of the first half received by hand directly into the bottle	141–167–11–53
No. II. Milk of the first half drawn by a sterile canula into the bottle	0–0–1–2
Nos. III. and IV Drawn by hand after more than half the udder had been emptied................	0–6–0–0 0–0–1–2

The bacteria in No. 1 may have come partly from the air, but most likely from the teats, which had become infected through their orifices with ordinary forms of cocci and bacilli. The hands of the milker may also have carried infection.

We have taken as our standard for the description of what the dairy farm should be the works of Rotch and Cautley and our own observation of the Walker-Gordon farm. This shows what is being done in the dairies which have accepted the standard set by the Philadelphia Milk Commission. It is interesting to note that the American standard for certified milk is equal if not superior to that of any other country.

Certified milk will probably command a higher price than average milk, at least for a long time; but it is not too much

to hope that with the increase of competition the general public will eventually obtain an approximately clean product of moderate price and infinitely superior to that which we have hitherto been forced to accept.

In view of the well-known excellence of the dairy products of Denmark it is worth our while to study the method of handling milk which is carried out in Copenhagen, Denmark.

The milk is brought to the company by various farmers, and only sound milk is received. By the regulations, the milk of any sick cow is paid for at the regular rates, also the wages of any employee who is suffering from an infectious disease. The milk is supplied to the consumer in sterilized bottles closed with clean new corks. The company guarantees veterinary control of all cows from which the milk is obtained and the exclusion of that from suspected animals; also the cooling of milk to 40° F. or lower at the farms and depots; also the purification of the total product by upward filtration through fine gravel; also absolute cleanliness of all bottles and cans which are stamped with the company's seal. The cows are inspected once every two weeks by a veterinary surgeon, and an inspector reports monthly on the fodder, state of the sheds, and the care exercised in the milking. During the summer the cows get fresh pasture, grass, and clover; in the winter, hay, oats, bran, and carrots.

The following is an extract from the regulations:

"The food of the cows must be of such a character that no bad taste or taint may be imparted to the milk by it. Brewers' grains and all similar refuse from distilleries are distinctly forbidden, as is also every kind of fodder which is not fresh and in good condition. Turnips and turnip leaves are strictly forbidden. Carrots and mangolds are allowed up to one-half bushel for each cow, but only when at least seven pounds of corn, bran, and cake are also given. Rape-seed cake is the only oil-cake which may be used. Stall feeding in summer is not allowed under any circumstances. Cows must be fed in the

open air on grass and clover. Vetches are forbidden. In the autumn the cows must be clipped on the udder, tail, and hind quarters before being taken in. The milk of cows newly calved must be withheld for at least twelve days, and must be not less in quantity than three quarts a day. Immediately after milking, in all seasons, the milk must be cooled to 40° F. in ice-water."

George T. Palmer,[217] in the *Philadelphia Medical Journal*, describes the Trinity Diet Kitchen which has been established in Chicago to supply a pure, modified, unheated cow's milk for infants in the poor district.

The milk is obtained from the farm of H. B. Gurler, of De Kalb, Illinois. Much the same precautions as those described by Rotch in relation to Laboratory Milk are employed on this farm. The cattle are mainly of Holstein breed, tuberculin tested, and carefully fed. Any cow which becomes sick is at once isolated from the herd in a separate building, etc. By a rapid process of cooling within from ten to twelve minutes after milking the temperature of the milk is reduced to 45° F., and within twenty minutes after milking it has been bottled and sealed. Such milk has been kept on ice in the Diet Kitchen for almost two weeks without souring. Not one ounce of either sterilized or pasteurized milk has ever been distributed from this Diet Kitchen. A plentiful supply of ice with each bottle, and rigid instructions to the parents with regard to absolute cleanliness in handling the milk, keeping it cold, and regularity in feeding, contributed largely to the good results obtained.

The following account of milk inspection as carried out by the New York Board of Health is given by Herman Betz [202] in the *Medical News* for March 10, 1900.

The inspection is carried out by a corps of "milk inspectors" who make visits at short intervals to all of the dairies in their respective districts. If the milk prove unsatisfactory by the lactometer and thermometer tests, a sample is taken for analy-

sis. This analysis includes the determination of (*a*) the percentage of water, (*b*) the total solids, (*c*) the fat, (*d*) the solids not fat, (*e*) the percentage low in solids, (*f*) the percentage low in fat, (*g*) the reaction, and (*h*) the presence of preservatives, such as borax, salicylic acid, or formaldehyde. The retail dealer does not receive his permit until the inspector has satisfied himself that the shop and premises are in satisfactory condition, and that hygienic cleanliness of the appliances has been obtained. If the dealer fails to maintain hygienic precautions, or if the milk analysis shows that it is more than five per cent. low in solids or three per cent. low in fat, or contains preservatives, the permit for its sale is either withheld or withdrawn until the requirements are met.

The wholesale dealer is required to give a list of the farms from which he obtains his supply, the breeds of cows employed, the precautions used in handling the milk, and the railroads on which it is shipped. In case of an epidemic of sickness occurring in any of the towns from which New York draws its milk-supply, notification is made to the Board of Health, and that portion of the supply, if in any way liable to infection, can be stopped. Each wagon of the wholesale dealer is required to have a separate permit, and the name and address of the driver is kept on file. Each permit, in store or wagon, must occupy a conspicuous place.

Edward B. Voorhees, in a Report on Food and Nutrition Investigations (abstract in the *Dietetic and Hygienic Gazette*, No. 13, 1897), asserts that the price of milk should be governed by its fat content. It is entirely practicable, under present conditions, for even the smaller producers and dealers to guarantee a product containing a reasonably definite quantity of fat, because the chief causes of variations in the quality of the milk are well known, and inexpensive instruments, simple in operation, are available for testing its fat content.

Huddleston.[72] The two kinds of cream furnished in New York City are gravity, hand-skimmed or Cooley cream, and

machine-skimmed or separated cream. The former has an average fat percentage of from twelve to sixteen; it is raised in Cooley cans to allow of drawing off the milk from below after it has been submerged in cold water for twenty-four hours. It is said to keep poorly, and a compound of borax and salicylic acid called "Preservitas" is often added thereto. Machine-skimmed cream or separated cream is quickly prepared and keeps well. Most cream is at least seventy-two hours old before it reaches the city. A surplus supply is often kept buried in ice for a considerable period. Certain dairies, however, send cream to the cities bottled and sealed while fresh. Cream thickens with age; during periods of cold weather it is a common practice to hold it back so that it may appear richer. This increase in density is due to the multiplication of bacteria.

Huddleston advocates the selling of milk and cream of known guaranteed fat percentages, and can find no reason why dealers should not supply cream as fresh as milk. Pasteurization can be practised at small cost at the dairy.

CHAPTER VIII.

BACTERIOLOGY.

That milk will sour if exposed to the air for a certain length of time is a fact so well known that it scarcely needs repetition, but it is only within recent years that we have been able definitely to determine the causative agents of this acidification,—namely, certain species of bacteria. We know also that the clots formed in this process will under certain conditions redissolve as the result of bacterial action. It is probable that further changes in milk occur from the presence of micro-organisms, but our knowledge on this subject is still in its infancy. At least we know that many of the products resulting from the presence of acid-producing bacteria in milk are distinctly harmful to the infant organism. While it is possible that some species of bacteria may be of service in preparing milk for the chemical changes it must undergo before it is ready for absorption, on the whole the harmful far exceed the helpful varieties of milk bacteria. It is fair, then, to assume that the freer a milk is from micro-organisms the more suitable it will be for the needs of the infant.

It is of course true that sterile milk becomes infected with bacteria as soon as it enters the mouth and the gastro-intestinal tract. When there is digestive disturbance, however, we will have reduced the etiological factors of disease by a very important item if we are able to exclude contamination of the milk-supply.

It must not be forgotten, in dealing with a milk which has well matured, that the ordinary methods of sterilization will destroy the group of lactic acid bacteria and leave the proteolytic or peptonizing group unharmed, and that toxic products may result from the presence of excessive numbers of pep-

tonizing bacteria. Since these two groups are naturally antagonistic, it may prove a questionable advantage to overthrow the balance between them. This in no wise changes the original dictum that milk should have a low bacterial content to be an ideal food for infants. Such milk requires no other preservative than a low temperature, and no objection has yet been offered to its use.

In the following pages we shall attempt to give a brief outline of what has been done in that branch of bacteriology which concerns itself with the micro-organisms found in milk.

Bacteria are found in the meconium within four hours after birth, from infection through the rectal orifice; somewhat later they gain entrance to the mouth from the air, bathing water, etc.[7]

SCHILL (*Zeitschrift für Hygiene und Infect. Krankheiten,* Bd. xix., 1895) and VON PUTEREN (quoted by Mannaberg in his work on Intestinal Bacteria, Vienna, 1895) consider that no amount of sterilizing can prevent the entrance of bacteria into milk fæces, even when the milk does not contain them. Infection probably comes from the swallowing of saliva. Langermann and Eberle have shown that almost sterile food will become infected through the stomach and intestines.

LANGERMANN found that the infant's stomach normally contained from 3700 to 240,000 bacteria, in nursing children from 6960 to 20,000, in the sick incomparably more, and, even in the presence of free hydrochloric acid, there were from 3200 to 6400. Free hydrochloric acid is not found constantly in the infant's stomach; it can serve only to diminish and not to suppress bacterial growth (*Jahrbuch für Kinderkrankheiten,* Bd. xxxv.).

EBERLE counted 33,000,000 micro-organisms in one milligramme of fresh fæces (only 1,500,000 to 3,000,000 by culture), even when sterile food was used (*Centralblatt für Bacteriologie und Parisitenkunde,* Bd. xix., 1896).

MIQUEL[105] has estimated the rapidity with which bacteria

multiply in cow's milk. The specimen contained 9000 bacteria in each cubic centimetre on its arrival at the laboratory two hours after milking.

One hour later it contained	21,750
Two hours later it contained	36,250
Seven hours later it contained	60,000
Nine hours later it contained	120,000
Twenty-five hours later it contained	5,600,000

Heat favors the multiplication of bacteria. In the same milk, after fifteen hours' exposure at 15° C., Miquel found 100,000 bacteria per cubic centimetre, while at 25° C. there were 72,000,000, and at 35° C. 165,000,000.

SEDGEWICK and BATCHELDER,[69] in Boston in 1892, found an average number of 70,000 bacteria per cubic centimetre of milk handled in the usual way and examined a few hours after milking. In fifty-seven samples of milk taken from the ordinary delivery wagons they found an average of 2,355,000 bacteria.

BACKHAUS'S investigations [85] show to what extent different factors contribute in influencing the bacterial contamination of milk.

Milking.

Dry milking	5,600 germs per cubic centimetre
Wet milking	9,000 germs per cubic centimetre
First milk	10,400 germs per cubic centimetre
Last milk	Sterile

Care of the Cow.

When the cow is cleaned	20,600 germs per cubic centimetre
When the cow is not cleaned	170,000 germs per cubic centimetre
Udder washed	2,200 germs per cubic centimetre
Udder not washed	3,800 germs per cubic centimetre

Air Contamination.

If the cow is milked in the open air	7,500 germs per cubic centimetre
If the cow is milked in a clean stall	29,250 germs per cubic centimetre
If the cow is milked in an unclean stall	69,000 germs per cubic centimetre

Vessels used.

Enamelled vessels	1,105 germs per cubic centimetre
Tin vessels	1,690 germs per cubic centimetre
Wooden vessels	279,000 germs per cubic centimetre

Clean Vessels.

Sterilized vessels	1,300 germs per cubic centimetre
Washed vessels	28,600 germs per cubic centimetre

Infection.

Fresh milk	6,660 germs per cubic centimetre
Milk passed through six vessels	97,600 germs per cubic centimetre

Straw.

Turf	40,000 germs per cubic centimetre
Good straw	150,000 germs per cubic centimetre
Dirty straw	200,000 germs per cubic centimetre

Water.

Fresh water	322 germs per cubic centimetre
Trough water	228,200 germs per cubic centimetre
Milk supplied from a good dairy farm	25,000 germs per cubic centimetre
Milk supplied to the Königsberg market	2,000,000 germs per cubic centimetre

CAUTLEY.[38] Human milk is usually considered sterile when there is no local disease of the breast. This is doubtless true of the milk contained in the gland. Escherich found the milk of twenty-five healthy women absolutely devoid of micro-organisms. On the other hand, Cohn and Neumann found microbes in the milk of forty-three out of forty-eight healthy women. The varieties of organisms most commonly present were the staphylococcus pyogenes, albus and aureus, and the streptococcus pyogenes. Honigmann made seventy-six examinations of the milk of sixty-four women, recently confined, and found it sterile on four occasions only. Ringel examined the milk of twelve healthy and thirteen ill nursing women, and found

it sterile in three only. The microbes are most numerous in the milk first secreted, and in all probability have made their way along the ducts in the nipple. The milk last poured out is quite sterile.

Marfan.[105] We may safely conclude that the milk of healthy mothers, obtained under aseptic precautions, contains micro-organisms nineteen times out of twenty. These are usually the staphylococcus albus or aureus (Honigmann, Paleske, Ringel, Knochenstirn, Genoud, Charrin, Trinci). These investigators are agreed in recognizing that only the first portions of the milk obtained contain micro-organisms, and that these organisms are found only at or near the orifices of the lactiferous channels and not in the depth of the gland; hence they are not the result of elimination by the mammary gland. They come either from the skin near the orifices in the nipple or from the infant's mouth.

These remarks as to the frequency of infection of woman's milk through the nipples apply equally well to cow's milk, only in the latter case the liability to infection is even greater. Lehmann and Schultz were among the first to demonstrate that cow's milk is practically never sterile.

The microbes which are found in cow's milk ordinarily gain entrance in one of the two following ways: most often they are introduced during the act of milking and the manipulations following it; less commonly the milk is rendered virulent by the presence of the germs of an infectious disease from which the cow is suffering. The first are the ordinary saprophytic germs which are universally distributed throughout nature and are not pathogenic; but they spoil milk and render it more or less toxic. Exceptionally, accidental infection of milk with pathogenic germs may occur.

The Saprophytic Microbes of Milk.[105]

Apart from infection of milk by organisms which make their way into the ducts of the nipple (which is of minor importance),

there are many fruitful sources for its further contamination. Soxhlet has isolated, in cow's milk, the following impurities: fæces, dust, and particles of hay, grass, and straw. Infection may also occur from the hands or person of the milker, from particles of dirt, hairs, etc., brushed from the animal's flanks and udder, and from the receptacles into which the milk is drawn. Substances added to milk, such as water, coloring matter, etc., may lead to infection. Marfan considers that infection from the air is of less importance than was formerly thought.

Lactic Acid Bacteria.[105]

The most frequent modification which milk undergoes is lactic acid fermentation. If fresh milk is allowed to stand, it first becomes acid in reaction and of a bitter taste. At the end of a period varying from one to four days, according to the temperature, coagulation occurs. This is due to the transformation of the lactose into lactic acid; from seven to eight per cent. of the latter is sufficient to coagulate the casein. When milk is heated, a smaller quantity of lactic acid is required for its coagulation.

Pasteur ascribed the transformation of lactose into lactic acid to the activity of a microbe which he called the "lactic ferment." This seems to be identical with the organism described by Hüppe as the "bacillus of lactic acid."

Leudet and Wurtz have established the identity of the "lactic ferment" with the bacillus lactis aërogenes of Escherich, and this, in turn, is closely allied to the bacillus coli communis of Escherich, which also causes lactic acid fermentation.

Marfan considers that the usual lactic ferments probably represent different varieties of the bacillus coli communis which are normally found in the intestine. Ordinarily they are saprophytic, but under certain conditions they may become pathogenic.

Freudenreich has collected the following list of organisms which cause lactic acid fermentation: the bacterium acidi

lactici of Grotenfeld; the micrococcus lactis I and II of Hüppe, the micrococcus acidi lactici of Marpmann, the streptococcus acidi lactici of Marpmann, the micrococcus acidi lactici of Krüger, the streptococcus acidi lactici of Grotenfeld, and the bacillus prodigiosus.

Certain pathogenic bacteria can acidify and coagulate milk: the staphylococcus pyogenes, the pneumococcus of Talamon and Fränkel, the micrococcus of contagious mammitis of the cow (Nocard and Mollereau), the micrococcus of gangrenous mammitis of sheep (Nocard), and the cholera bacillus (Netter, de Hann, A. C. Huysse). The streptococcus of erysipelas acidifies milk without coagulating it (Löffler).

In the Twelfth Annual Report of Storr's Agricultural Experiment Station, Connecticut (1899), H. W. Conn has published a "Classification of Dairy Bacteria" which comprises the results of his investigations for the past ten years. Over two hundred different types of bacteria have been found which may be regarded as more or less distinct from one another. In his description he has followed as closely as possible the method adopted by Fuller and Johnson in their recent publication on water bacteria, and has thereby endeavored to establish a uniform system of classification which shall serve as a basis for bringing together the work of American dairy bacteriologists. The need for such a system can scarcely be overestimated, as without a standard for comparison the work of many individual observers must go for naught.

Conn concludes that the dairy organisms of New England are chiefly of four species, or, more strictly, three groups of closely related bacteria, namely,—

The bacterium acidi lactici of Esten. This variety is very generally found in samples of milk and cream from a wide area of territory. In sour milk it is almost always present. Its frequent occurrence in milk, together with its markedly anaërobic character, would seem to indicate that it probably comes from the milk-ducts. Conn's recent experiments (draw-

ing the milk directly from the teats into sterilized vessels, with little or no chance for contamination) seem, however, to point to the conclusion that this organism comes from external contamination.

The variety of micro-organism next in frequency is No. 202 on the list. This species differs only slightly from the bacterium acidi lactici, and the two species undoubtedly belong together. They represent a type of dairy organism common everywhere. Many of the lactic acid organisms hitherto described by different bacteriologists clearly belong to this type, although slight differences in described characteristics perhaps indicate different varieties. This is true of the bacterium acidi lactici of Gunther and Thierfelder, bacterium lactis acidi of Leichmann, bacillus XIX of Adametz, bacillus a of von Freudenreich, micrococcus acidi lævolactici and bacillus acidi lævolactici of Leichmann, and several types described by Storch.

The next most important dairy species described by Conn is No. 208, which he regards as identical with the bacillus lactis aërogenes. This is found almost universally, although never in very great numbers. It is quite possible that a number of distinct types are included under this head, as the organisms have shown wide variations. The distinctive characteristics of these species are: (1) the intense acid produced in litmus gelatin; (2) the abundant production of gas in milk-sugar, bouillon, or milk; (3) the uncertainty as to their power of curdling milk, this occurring commonly at high temperatures, though not at the temperature of the room; and (4) the distinctive odor of sour milk which they produce after curdling.

According to Conn's observations, ordinary sour milk is produced by the three organisms mentioned, and probably in the spontaneous souring of milk all three are present.

It is probable that there belong to this group also the original bacillus acidi lactici of Hüppe, the bacterium lactis acidi

of Marpmann, the bacillus acidi lactici I and II of Grotenfeld, No. 8 of Eckels, and doubtless several others.

Finally, Conn describes the micrococcus lactis varians. This species is common in fresh milk and probably exists in the milk-ducts. It is often overgrown by the lactic organisms and is less often found in old milk.

Peptonizing Bacteria.

[105] The ferments of casein or peptonizing bacteria are saprophytes belonging to the groups of which the bacillus subtilis and bacillus mesentericus vulgatus are the prototypes. These microbes act on casein through the products which they secrete. They coagulate casein without acidifying the milk by the aid of a ferment resembling lab, and they liquefy the coagulum and peptonize it by means of a ferment called "casease" (Duclaux). The peptone resulting from this is called "caseone." It is only at the end of lactic acid fermentation that the activity of the peptonizing bacteria begins.

The ferments of casein comprise several species of microbes, of which the most important are the bacillus subtilis (hay bacillus), the bacillus mesentericus vulgatus (potato bacillus), and the tyrothrix group. The bacillus subtilis and the bacillus mesentericus vulgatus are aërobic organisms and universally distributed. These two species are poorly defined and many varieties can be included among them. The characteristics of these ferments are, that they utilize the casein after the first steps of digestion have rendered it assimilable, and transform it into various products which are found wherever microbes are acting upon albuminoids,—namely, leucin, tyrosin, urea, ammonium carbonate, acids of the fatty acid series (formic, acetic, propionic, butyric, valeric), ammonia and ammoniacal compounds, carbonic acid, water, hydrocarbon gases, hydrogen, and nitrogen.

Nearly all the peptonizing bacteria produce spores which can resist temperatures higher than 100° C. Flügge and

Lübbert have utilized this property for the isolation and study of the peptonizing bacteria, several varieties of which they have proved to be pathogenic. Lesage has also encountered in fermented milk a bacillus mesentericus with pathogenic properties.

The bacillus subtilis and bacillus mesentericus vulgatus are, as a rule, not found in the fæces of the breast-fed infant. When they are present, they are not numerous unless digestive troubles exist; usually they are not virulent (Marfan).

FLÜGGE.[199] Enormous numbers of peptonizing bacteria can be present in a milk which is apparently normal and free from germs. Flügge asserts that the peptonizing and the most resistant anaërobic bacteria are not destroyed, though subjected to a temperature of 100° C. for three-quarters of an hour. If such a milk is kept for several days at a temperature exceeding 22° C. (72° F.), or for a few hours at a temperature above 26° C. (79° F.), these bacteria will grow much more luxuriantly than in unheated milk, since in the latter the excessive number of lactic acid bacteria will hinder the development of other forms.

KLIMMER[251] states that peptonizing bacteria are usually introduced into milk with dirt (dried fæces). They are among the chief causes of summer diarrhœa of infants.

DUCLAUX[230] calls attention to the fact that peptones are the normal product of digestion, and that countless millions of peptonizing bacteria are normally present in the intestines. Therefore it would seem questionable whether the addition of a few more would make any material difference. He thinks that the harm resulting from their presence has probably been overrated.

WEBER[182] has made a very thorough study of the effect of sterilization on the bacterial content of milk. He emphasizes the antagonism between the lactic acid and the peptonizing bacteria, and points to a possible danger from the use of the sterilized product. His conclusions are as follows:

I. The methods of sterilization of milk in use at the present time are not sufficient to give us with absolute certainty a germ-free milk. The so-called sterilized milk of the different dairies has a varying bacterial content. The higher the percentage of negative tests for bacteria the greater are the alterations brought about by the process which are already visible to the naked eye.

II. The anaërobic bacteria play no considerable rôle in commercial sterilized milk, so far as these tests showed.

III. Of the aërobic bacteria the thermophile are of no great practical importance, on account of their faculty of growing only at high temperatures. On the other hand, they may lead to errors in bacteriological investigations, since milk decomposed by them will, when tested by culture experiments, seem apparently germ-free.

IV The aërobic bacteria isolated from sterilized milk all have the property of peptonizing casein.

V. Apart from the group of thermophiles we can distinguish three groups of aërobic peptonizing bacteria, namely,—

(*a*) Bacteria which decompose the milk rapidly within from twenty-four to forty-eight hours. Most of them grow well at room temperature. Most of them peptonize the casein without attacking the milk-sugar; but some are also capable of breaking up the lactose with the formation of strong acid.

(*b*) Bacteria which under the most favorable conditions decompose the milk only after five to seven days, usually when the reaction is weakly acid or amphoteric. Nearly all of them grow best at high temperatures, as well at 37° as at 50° C. One species grew well at 60° C.

(*c*) Bacteria which do not alter the appearance of the milk, although they grow well.

VI. A number of these peptonizing bacteria can cause putrefactive decomposition of cow's milk (sterilized) and form in this process sulphuretted hydrogen. Previous to its formation the casein must be peptonized.

VII. Lactose serves to check putrefaction in milk in so far

as it favors the development of acid-producing bacilli which suppress the activity of the peptonizing bacteria. This peculiarity of lactose is fully developed in raw milk. On the other hand, in milk which has been heated and so freed from the real acid-forming bacteria, this property is not in evidence or only to a very limited degree. Consequently in heated milk bacteria develop which are not found in raw milk, and which cause putrefactive decomposition of the milk. The use of so-called sterilized milk (commercial) for infant feeding would seem, then, to be not without danger, since the bacterial flora present in this product favor the occurrence of putrefactive changes.

VIII. The so-called "toxic" peptonizing bacteria of Flügge also occur in commercial sterilized milk, but not very frequently. Only three out of one hundred and fifty tests showed the presence of these bacilli. Their mode of growth places them in the group of hay bacilli. They are remarkable for their ability to decompose albuminous substances and to form sulphuretted hydrogen. In this peptonizing power seems to lie the chief danger for the infant organism.

Kalischer[204] experimented with one variety of peptonizing bacteria and found that they produced a soluble ferment capable of inverting cane-sugar but not milk-sugar. They did not attack the fat, and there was no evidence of diastatic fermentation. They form from casein, albumose, and later peptone, besides ammonia, volatile acids, leucin and tyrosin, aromatic oxyacids, and a mixture of bases. Indol, skatol, phenol, and cresol were not found. The ferments produced by these bacteria resemble very closely in their action lab and trypsin, except that the latter is not known to produce aromatic oxyacids.

Besides these main classes of bacteria, there are certain varieties which cause changes in milk the exact clinical significance of which is not thoroughly understood. Their presence ren-

ders the use of such milk undesirable if not unsafe; fortunately, their presence can readily be detected.

The bacillus cyanogenes or syncyanus, which is only active in acid milk, and the bacillus cyaneo-fluorescens of Zangemeister cause a blue color in milk. A red color is due to the presence of the micrococcus prodigiosus, the sarcina rosea, the bacillus lactis erythrogenes, and the saccharomyces rubra. A yellow color is due to the bacillus synxanthus. Mossler and Zundel have proved that the ingestion of such colored milk can set up a gastro-enteritis (Marfan).

Certain micro-organisms have the property of rendering milk viscous. These are the micrococcus of Schmidt-Mühlheim, the actinobacter (Duclaux), the bacillus lactis pituitosi (Löffler), the bacillus lactis viscosus (Adametz), the streptococcus Hollandicus (Weigmann), the micrococcus of Freudenreich, the bacterium of Guillebeau, the bacterium Hessii, etc.

Certain yeasts are also found, especially in milk which has undergone coagulation. Among these are the saccharomyces lactis, the saccharomyces rubra, and the penicillium glaucum.[105]

Marfan.[105] Of the various organisms described, the groups of lactic acid and peptonizing bacteria are most to be feared. They may do harm in one of two ways: either by their presence in excessive numbers (this is more apt to occur during the summer months when conditions are favorable for their rapid multiplication) or through the products of their activity, such as butyric, lactic, propionic, and valeric acids, or leucin, tyrosin, ammoniacal compounds, and fatty acids. Among other toxic products which result from bacterial activity especial attention should be called to tyrotoxicon, isolated by Victor Vaughan, of Ann Arbor, from putrefied cream and cheese, and spasmotoxine, found by Brieger in putrefied milk.

The Transmission of Infectious Diseases by Milk.

Wyssokowitsch established the law that healthy glandular epithelium does not permit of the passage of microbes. Basch

and Weleminsky,[195] in experimenting with pathogenic germs, have found that only those bacteria pass into the milk which give rise to hemorrhage or local disease of the mammary gland; in other words, bacteria are not excreted by the mammary gland, but enter the milk only when the natural barriers are broken down by hemorrhagic or other necroses.

Tuberculosis.

It is certain that the milk of phthisical animals can cause tuberculosis in laboratory animals fed on it or inoculated with it under the skin or in the peritoneum. Tubercular disease of the udder or teat of the cow will almost certainly give rise to tubercular infection of the milk; when the disease is confined to other parts of the body, the milk of the animal may or may not contain tubercular virus. Bollinger, Nocard, and Galtier consider that the milk is certainly virulent only when the teat is affected by tuberculosis; on the other hand, Bang, Csokor, Ernst, Hirschberger, and Koubassoff have found the milk virulent even when the disease was limited to other parts of the body. All are agreed that the diagnosis of mammary tuberculosis in its early stages is very difficult.[105]

Clinical evidence has proved that milk from tubercular animals can, and undoubtedly does, give rise to tubercular infection through the gastro-intestinal tract; however, tuberculosis by ingestion is much less frequent than tuberculosis by inhalation.

Holt believes that the danger of transmitting tubercular infection to infants by cow's milk is greatly exaggerated. Recorded cases of such infection are extremely rare. In a series of one hundred and nineteen autopsies on tubercular patients, nearly all infants, he found no instance of it. Northrup, in his large experience, came across but one undoubted case.

H. Johnson Collins[27] calls attention to the rarity of tubercular infection in infants from raw milk. The inves-

tigations of Gregari, Strauss, and Wurtz show that, so long as the gastric juice retains a normal degree of acidity, tuberculosis of the alimentary canal is unlikely to occur. Kurlow and Wagner consider the gastric juice to be a strong bactericidal agent.

At a meeting of the Medical Society of the County of New York, January 29, 1900,[234] H. W. Conn, of Wesleyan University, stated that it is still uncertain whether tuberculous processes in the cow which were localized in parts of the body other than the udder would lead to the appearance of tubercle bacilli in the milk of that animal. Of course this does not refer to general tuberculosis. From the fact that primary intestinal tuberculosis in man is rare, and because it is probable that the organisms of human and of bovine tuberculosis are not identical, Conn thinks that there is good reason for believing that the danger of contracting tuberculosis from drinking milk has been greatly exaggerated.

Koch,[261] at the recent meeting of the British Congress on Tuberculosis, July 23, 1901, emphasized that human and bovine tuberculosis were distinct forms of infection and could not be transmitted from one species to the other. He based these statements on animal experiments with human tubercle bacilli and on the rarity of primary intestinal tuberculosis in man. In the few positive cases in which this had occurred among thousands of autopsies he considered that it was impossible to exclude accidental infection with the widely propagated bacilli of human tuberculosis. He believes, therefore, that the infection of human beings with bovine tuberculosis is of very rare occurrence.

Whether the milk of a tubercular woman can affect the nursing infant is also a matter of dispute; the conditions may fairly be considered analogous to those in the cow. Roger and Garnier, in the *Semaine Médicale,* February 23, 1900 (abstract in the *Philadelphia Medical Journal,* June 23, 1900), report a case in which tubercle bacilli were isolated from the milk

of a woman suffering from pharyngeal and pulmonary tuberculosis. The milk, when injected into a guinea-pig, caused death in thirty-three days, with typical generalized lesions.

While the milk of a tubercular animal may contain no tubercle bacilli, it is possible that the toxins elaborated by them may be present and constitute a source of danger to the infant using such milk.

As milk furnishes a good culture medium for most varieties of bacteria, its accidental infection with the germs of any of the infectious diseases, such as cholera, typhoid fever, diphtheria, etc., will render such a milk unfit for use.

Diseased conditions of the cow, such as aphthous fever, infectious mammitis, anthrax, etc., or, in the woman, pneumonia, typhoid fever, scarlet fever, etc., will also constitute a contra-indication to the use of their milk [105] (see page 169, Bendix).

It seems hardly necessary to enumerate all the other micro-organisms which have been found in milk. Owing to the lack of uniformity among different observers in their methods of study and in their descriptions of bacteria, it seems probable that numerous duplicates of the same species have been described as distinct entities (Conn). For the purposes of infant feeding it is not necessary to consider more than the three main groups,—namely, the lactic acid group, the proteolytic or peptonizing group, and what may be called the pathogenic group. According to Escherich, the bacillus coli communis can be included among the first, since it possesses the power of splitting up lactose into lactic acid.

The rôle played by bacteria in the gastro-intestinal tract remains to be briefly discussed. Investigations to determine the relation which bacterial activity bears to the digestive processes give us, at best, unsatisfactory results, since it is manifestly impossible to reproduce the conditions which obtain in the intestines of the living organism.

Biedert [7] considers that intestinal putrefaction is held in check principally by:

I. Free hydrochloric acid, which is at its maximum in breast-fed children in the intervals between feedings (Langermann).

II. Lactic acid, which prevents the other forms of fermentation in the stomach and small intestines (Biedert, Escherich, Richet).

III. Fat and fatty acids in the large intestines.

IV. The absorption at the right time of the water and albuminoid constituents of the food, thus leaving the lower intestine poor in these materials, and preventing the excessive growth of bacteria until the whole is excreted with the fæces. Gilbert and Dominichi came to the same conclusions (Discussions of the Biological Society, Paris, 1894). They found fewest microbes in the duodenum; from that point their number increased until it was greatest at the ileo-cæcal valve, to decrease towards the rectum and anus.

Escherich (*Deutsch. Med. Woch.*, October 6, 1898) emphasizes the antiseptic action of lactic acid fermentation, and draws attention to the fact that the gastric juice of infants fed on cow's milk is a poor disinfectant, since so little free hydrochloric acid is present.

Biedert [7] finds that the bacteria chiefly concerned in fermentative processes are:

I. The bacillus lactis aërogenes, which predominates in the upper part of the small intestine. It splits up lactose into lactic acid, carbon dioxide, and water, and thus ferments the chyme. By the production of acid it maintains an acid medium or reaction.

II. The bacillus coli communis, which predominates in the lower intestine. It may flourish in either acid or alkaline media, and is capable of forming acid out of lactose. It is able to split up neutral fats into fatty acids, which it does chiefly in the large intestine.

The latter is the predominating germ of the fæces. Other forms are also found, such as the hay bacillus, the tetracoccus,

the white and red hay bacillus, the capsulated hay bacillus, numerous cocci, etc.

ESCHERICH.[48] The bacillus lactis aërogenes owes its predominance in the small intestine to the lactic acid which it produces, in connection with its power to live on the products of the decomposition of sugar in the absence of oxygen. Not until the sugar is exhausted in the colon is the field free for other bacteria. First, the bacillus coli communis, which lives on remnants of sugar and albumin and busies itself in splitting up fats. It is also an agent of putrefaction, acting on the casein residues, which are often considerable in artificially fed children. Where the bacillus lactis aërogenes gives way to the bacillus coli communis at the end of the ileum, we find that the intense acid reaction becomes weaker and yields to an alkaline reaction, due to the greater activity of the intestinal and pancreatic secretions. At this point the protection which lactic acid had given to the casein ceases (Schlichter). The acid reaction, especially in the case of breast-fed children, persists until near the end of the small intestine (Biedert, Heubner).

The breast-fed child leaves only a small casein remnant, but a relatively greater sugar and lactic acid remnant. Out of the (comparatively) large fat remnant the bacillus coli communis forms fatty acids in considerable quantity, thus prolonging the acid reaction. When the infant is artificially fed, casein with its lime salts and its other alkaline products is apt to be conspicuous in the food residue. Its presence checks acid fermentation.

Bacteria undoubtedly serve the purpose of helping to disintegrate food-stuffs, especially those of tenacious vegetable fibre (von Hoffmeister in Neumeister's "Text-Book of Physiological Chemistry," vol. i., 1893-1895). This action may be a harmless one or may result in the formation of noxious products. When the infant is healthy, the intestine is emptied before any marked production of toxins occurs.

Schlossmann [136] has conducted a series of experiments on the starch-decomposing properties of certain bacteria. He used pure cultures of the bacillus lactis aërogenes and the bacillus coli communis, and found that relatively high percentages of starch were decomposed without the production of sugar. He concludes, therefore, that it is probable that a greater or less proportion of the starch in an infant's diet cannot be utilized for the needs of the organism. Since the conditions of the experiment can hardly be said to reproduce those which obtain in the gastro-intestinal tract of the infant, it would seem that his conclusions cannot possess much clinical value.

Biedert draws attention to the fact that the addition of starch and lactose to the infant's diet favors the production of an acid reaction. Baginsky and Moro have also found that the bacillus coli communis and the bacillus lactis aërogenes can decompose starch without the production of sugar.

Escherich has proved that different forms of bacteria can split up sugar. As gas is produced, which passes off with the fæces, he thinks that a portion of the sugar would thereby be lost for the needs of the organism.

Hammarsten calls attention to the fact that, besides the action of enzymes in the intestinal tract, we have to take into consideration fermentative and putrefactive changes due to the action of bacteria. These are less intense in the upper bowel, increase as we descend to the ileo-cæcal valve, and then diminish in the large intestine, sigmoid flexure, and rectum.

So long as the intestinal reaction is strongly acid, fermentation occurs, but not putrefaction. Gamgee asserts that the amount of acid formed by the organized ferments is so great that the intestinal content, from the pylorus to the cæcum, is always acid in reaction.

Intoxications through Milk.

Sonnenberger [205] lays stress on the possibility of intoxication by plant alkaloids which have gained entrance into the

milk from the fodder. Biedert, Meinert, Gaertner, Alt, and Scholl have also testified their belief that enteric diseases in the infant can have their origin in intoxications from this source. Scholl emphasizes the importance of careful inspection of the fodder, since the alkaloids and toxins contained in the milk of cattle fed on these poisonous weeds cannot be purified with certainty by the Soxhlet process.

We know that the mammary gland, besides its other properties, possesses that of eliminating poisons; this has recently been demonstrated conclusively by Fröhner (*Monatsheft für Prakt. Heilkunde,* Bd. ii.). Schneidemühl, in his "Text-Book of Comparative Pathology," vol. ii., 1896, makes this statement regarding the excretion of poisons by the mammary gland: "Milch-cows have a greater power of resistance against poisonous substances than other animals, because the heightened activity of the mammary gland brings about a more rapid and complete elimination of the poison (which has found entrance) than in other animals."

The source of these poisons is to be found in the plant alkaloids; even in minute amounts their ingestion in milk may give rise to serious symptoms, although the cattle which have fed on the plants containing them show no symptoms of poisoning. The poisonous weeds are most often found in clover fields; among them are colchicum, digitalin, hyoscyamus, papaver somniferum, conium maculatum, hellebore, euphorbia, sinapis, etc.

CHAPTER IX.

STERILIZATION AND PASTEURIZATION.

Most authorities are agreed as to the advisability of the use of heat in preparing milk for an infant's meal, differing only in their choice of the degree to be employed. On the other hand, it is well recognized that the ideal to be always sought for is milk obtained and handled with such strict precautions as to be nearly sterile and kept free from contamination until administered. Such a milk does not require any process of heating for the destruction of germs, but unfortunately its production is limited in amount and necessitates such expense as to place it beyond the reach of all but a favored few. In preparing food for the majority of infants, at least during the summer months, we will have to employ some degree of heat.

Jacobi [76] says that "as long as cows are tubercular, and milk is exposed to contagion from scarlet fever, diphtheria, typhoid fever, etc., as ordinarily obtained it needs to be boiled." H. J. Campbell,[29] however, calls attention to the fact that foul milk cannot be rendered safe by any amount of boiling or by other methods, apropos of which is the report by Marfan [105] of an epidemic of severe gastro-enteritis in children fed on sterilized cow's milk. The milk was sixteen hours old when sterilized, allowing sufficient time for the development of toxic substances which are not affected by sterilization.

Jemma,[236] in the *Rev. Mens. des Mal. de l'Enfance,* vol. xviii., No. II., reports the results of his studies on the milk of tubercular animals. He found that young rabbits fed on sterilized milk containing dead tubercle bacilli died within from fifteen to twenty days of advanced cachexia or later of marasmus. Other cases fed on plain sterilized milk or on their mother's milk flourished. The autopsies showed only

enteritis and fatty degeneration of the liver. It is therefore erroneous to believe that boiling or sterilization obviates the dangers of using milk from tubercular animals.

Failures in infant feeding will continue to occur, even when the milk administered is absolutely sterile, for, as Wellington Stewart [126] has pointed out, such a milk becomes alive with micro-organisms a few minutes after its ingestion. No one will deny, however, that the healthy infant can more successfully digest a pure milk than one contaminated with germs, many of which may be entirely foreign and harmful to a marked degree.

Methods of heating Milk.

Three methods are recommended,—namely, pasteurization, sterilization, and boiling. Great confusion exists in the use of the term "sterilization." As will be seen, complete sterilization cannot be obtained at 100° C. in less than from one and a half to two hours. Unless the method employed is accurately described, however, it is impossible to decide whether such a complete process or its equivalent has been carried out. As a general rule, the term seems to be applied to any process which carries the temperature to or above 100° C. for a certain time in some sort of an apparatus. This may or may not secure the absolute destruction of all germs, but for purposes of discussion the terms pasteurization, sterilization, and boiling may be accepted as defined below.

Pasteurization.

This method has taken its name from part of a process which Pasteur recommended very successfully for the preservation of wine and beer.

To R. G. Freeman, of New York, the credit belongs of having drawn the attention of the profession in this country to pasteurization, and of devising an apparatus for the preparation of milk in this way. He recommends that milk should

be heated to a temperature of 68° C. (155° F.) for thirty minutes. This destroys most of the bacteria, including those of tuberculosis, typhoid fever, and diphtheria, and causes practically no chemical change in the milk, not even altering its taste.

Holt defines pasteurization as that method by which the temperature is raised to, and maintained at, 75° C. (167° F.) for twenty minutes. This destroys the bacilli of cholera, typhoid, diphtheria, and tuberculosis, the bacillus coli communis, and ordinary pathogenic germs. It does not destroy spores, and milk so prepared will keep for two or three days at room temperature. It does not alter the taste; moreover, the character and digestibility of the curd are not affected. Whether there are any changes in the nutritive value of the milk is a point not yet settled. Holt believes that pasteurization is sufficient for ordinary purposes, but that in cities during very hot weather, when ice is scarce and milk highly contaminated, sterilization is imperative.

Cautley [38] considers that pasteurization at from 70° to 75° C. (158° to 167° F.) for thirty minutes, followed by rapid cooling in clean, well-stoppered bottles, is sufficient for all practical purposes. Such a milk should not be kept longer than from twelve to twenty-four hours. It is not seriously changed either chemically or in its taste; therefore he recommends it as a general rule.

Freeman.[55, 56, 157] Pasteurized milk was distributed during a period of three years to the poor of New York City in the summer months. Routine dilutions were used: in some, milk and water in equal parts plus lactose and lime-water; in others, milk and barley-water equal parts plus cane-sugar. During the three years of its use the number of deaths from diarrhœal diseases was less by eight hundred and sixty than in the three preceding years. Over one million bottles were given out during this time.

F. Siegert, of Strasburg, calls attention to the fact that,

since the year 1893, Forster, of Amsterdam, had employed pasteurization at 65° C. (150° F.) for fifteen minutes, and had found the results satisfactory in freeing the milk from pathogenic germs. Siegert carried out the same method in Strasburg on a large scale with good results.

LEEDS [93] draws attention to the practical sufficiency of pasteurization as regards the destruction of pathogenic germs, and is in favor of carrying out the process immediately after milking. The advantages claimed for this method are that the temperature of the milk need be raised only from 98.4° F. (blood-heat) to 157° F. (instead of from 40° to 50° F., the usual temperature at which milk is kept). This saves expense and prevents the development of bacteria and the production of toxins.

MONTI advises to heat milk to 60° C. (140° F.) for ten minutes, then to cool to 6° or 8° C. (42.8° or 46.4° F.). The milk should be kept at this temperature until used. This process kills most of the germs and prevents sporulation without alteration of the milk constituents.

RAVENEL [260] gives Sternberg's table of the thermal death-point of some of the most important bacteria.

Bacillus diphtheriæ	58° C. (136° F.) for ten minutes
Typhoid bacillus	56° C. (133° F.) for ten minutes
Pneumococcus	52° C. (125° F.) for ten minutes
Bacillus coli communis .	60° C. (140° F.) for ten minutes
Bacillus acidi lactici	56° C. (133° F.) for ten minutes
Staphylococcus pyogenes aureus	58° C. (136° F.) for ten minutes
Staphylococcus pyogenes albus	62° C. (144° F.) for ten minutes

BANG, of Copenhagen,[259] found that a temperature of 60° C. (140° F.) for fifteen minutes was sufficient to destroy all the tubercle bacilli in milk, so as to prevent infection when they

were injected into the peritoneal cavity; this degree of heat was sufficient to weaken the bacilli so that after pasteurization for two minutes they were incapable of infecting through the alimentary canal. In another series of experiments higher temperatures—70° C. (158° F.), 75° C. (167° F.), and 80° C. (176° F.)—were applied to milk from tuberculous udders, but sometimes failed to destroy the tubercle bacilli. Since the milk was heated in open bottles, the failure to destroy the germs was ascribed to the uneven application of the heat to the pellicle and to the foam on the surface of the milk.

Theobald Smith[255] had previously discovered from experiments with pure cultures of tubercle bacilli in different media that a temperature of 60° C. (140° F.) for fifteen minutes was sufficient to destroy all the bacilli, and that most of the germs were destroyed within from five to ten minutes. He did not obtain equally good results with tubercle bacilli in milk, and considered that this was due to the protection of the pellicle. H. L. Russell, of Wisconsin University, obtained similar results. He found that heating to 60° C. in closed bottles destroyed the tubercle bacilli in ten minutes.

Forster[260] gives the thermal death-point of the tubercle bacillus as follows: 65° C. (150° F.) for thirty minutes, 68° C. (155° F.) for fifteen minutes, 75° C. (167° F.) for ten minutes.

Blackader.[207] Wroblewsky has called attention to the fact that certain of the calcium salts which are normally soluble are made to enter into insoluble combinations by high temperatures, while Duclaux has pointed out that the gastric ferments are effective only in the presence of minute quantities of calcium and other mineral salts, the mineral varying with the specific form of fermentation (see Conradi). If the calcium salts are rendered insoluble by heat, then the coagulation of casein will to that extent be arrested or delayed. In corroboration of this view we know that boiled milk undergoes coagulation by rennet only with much difficulty. Since this

primary coagulation in the stomach appears to be necessary for the normal digestion of milk and its absorption into the system, it is certainly questionable whether, as a rule, boiled milk can be absorbed and assimilated as readily as milk which has not been brought to a temperature sufficient to change the condition of its calcium salts. On the other hand, this action may sometimes be of distinct advantage in those conditions of the infant's stomach in which the action of rennet, either directly or reinforced by the presence of fermenting bacteria, is so intense as to lead to the development of firm curds.

Blackader thinks that unheated milk probably contains ferment-like bodies which, when absorbed, are of distinct value to the organism. Babcock and Russell (Fourteenth Annual Report of the Wisconsin Experiment Station) discovered that milk obtained in a condition of perfect sterility undergoes self-digestion owing to the presence of a trypsin which is readily destroyed by heat. Blackader prefers to use always good unheated milk. When this cannot be obtained, he employs a temperature of 60° C. (140° F.) for fifteen minutes.

Conradi [240] found that the subjection of milk to temperatures of over 80° C. (176° F.) lowered the coagulation point of the milk in the presence of lime and similar salts from 8° to 12° C.; on the other hand, postponing the process of lab-coagulation. These facts prove that temperatures of over 80° C. cause a lasting chemical and physical alteration in the milk.

Troitsky [141, 142] considers it established that ordinary lactic acid ferments and pathogenic bacteria encountered in milk, including tubercle bacilli, are destroyed by a temperature of 80° C. (176° F.) for ten minutes or 68° C. (155° F.) for thirty minutes. The casein ferments resist heat much better. The bacillus subtilis, tyrothrix tenuis, and bacillus mesentericus vulgatus produce spores which are only destroyed at very high temperatures. If the adult germ succumbs at about 100° C., its spores can resist a temperature of 115° C. for one minute.

JACOBI [19] thinks that for the purpose of pasteurization "milk should be subjected to a temperature of from 65° to 68° C. (150° to 155° F.) for twenty minutes, but that it may be wise to extend the process over a longer time."

JOHANNESSEN [208, 239] thinks that with proper precautions as to the feeding of cows, etc., we may hope to obtain milk which is primarily free from germs. Under the present conditions milk must be pasteurized and then kept cool (below 18° C.), and administered within twelve hours. Heating to 70° C. for some time destroys pathogenic germs without altering to any extent the chemical composition of the milk.

VON STARCK [148, 150] believes in the efficacy of pasteurization to destroy pathogenic germs.

GETTY [68] had milk pasteurized at 75° C. (167° F.) for twenty minutes put in separate sterile bottles plugged with sterile cotton, cooled immediately and kept on ice. This was distributed during June, July, August, and September to a large number of children at Yonkers, New York. He asserts that a reduction of seventeen per cent. in the total mortality was effected during the two years of its use, and that the number of deaths from digestive disturbances was reduced almost one-half.

HÜPPE [133] believes that milk is best treated from a physiological stand-point by the application of heat under 75° C., since greater temperatures produce chemical changes.

H. JOHNSTONE CAMPBELL [29] thinks that pasteurization presents fewer disadvantages than sterilization; hence it is generally to be preferred.

J. LEWIS SMITH [129] thinks that pasteurization should always be recommended and never a higher temperature.

CAMPBELL [219] suggests a cheap method for home pasteurization. The necessary articles are (*a*) a jar, the cork of which is perforated for (*b*) a chemical thermometer, and (*c*) sterile non-absorbent cotton. The jar is filled with the milk to be pasteurized, the cork, with the thermometer in place, inserted,

and the whole placed in a saucepan of water and heated until the temperature of the milk reaches 160° F. The saucepan is then set at the back of the stove for twenty minutes. The cork is next replaced by a cotton plug, and the milk is ready for use or to be cooled and kept until wanted. The whole outfit can be obtained at the cost of about one dollar.

Carstairs Douglass, in the *Glasgow Medical Journal*,[220] suggests that the unpleasant taste of boiled milk is in large part due to the film which forms on the sides of the vessel above the bubbling fluid. As the fluid subsides, this film becomes overheated and charred and is carried back into the milk at its next ebullition. In proof of this he has noted that if milk is boiled in a flask and constantly agitated, the alteration in taste is much less. Douglass firmly believes in some vital property of fresh milk which a temperature of 100° C. destroys; hence he prefers pasteurization.

Objections to Pasteurization.

Marfan [105] objects that pasteurization requires complicated apparatus and the milk must be cooled rapidly afterwards. It keeps good for a short time only, and one is never sure that all the lactic ferments have been destroyed; therefore he does not recommend it.

Comby [62] considers that pasteurization is useful to preserve the milk, but that all the pathogenic germs are not destroyed.

Biedert [7] asserts that the lactic acid bacilli are destroyed by pasteurization, while the proteus and the coli groups are not affected. He recommends this method only for institutions in which the danger of milk contamination is minimized.

Koplik.[80, 81] Pasteurization destroys the pathogenic germs of most known diseases, but it does not destroy the milk bacteria which are much more frequently the cause of trouble. Most of these fall under three groups: A. Those which form lactic acid. B. Those which form butyric acid. C. Peptonizing bacteria. Groups B and C are not affected by any

temperature at or below 100° C., although cold inhibits their growth. Heating to from 90° to 92° C. destroys Group A. Since Groups B and C are not destroyed by pasteurization, he considers milk so prepared an uncertain and at times a dangerous food. He therefore advises sterilization for ten minutes at either 90° or 100° C. He has observed various forms of "milk infection" in infants fed on pasteurized milk.

Sterilization.

Marfan.[119] Miquel found that all germs are killed at the end of one hour by heating to 105° C., at the end of half an hour by a temperature of 107° or 108° C., and at the end of fifteen minutes by a temperature of 110° C. Troitsky states that sterilization is complete only after exposure to 100° C. for from one and a half to two hours, or even longer. Complete sterilization of milk, therefore, can only be accomplished by heating it to 100° C. for from one and a half to two hours, to 105° C. for one hour, to 107° or 108° C. for half an hour, or to 110° C. for fifteen minutes. (Higher degrees of temperature, daily sterilization at 100° C. for thirty minutes during three days, so-called fractional sterilization or Tyndallization, or heating in a special apparatus (autoclave) where the pressure can also be raised, would all serve the same purpose, but practically these methods are not in use.—Editors.)

To Soxhlet, as Jacobi well says, belongs the immortal merit of having systematized and popularized the method of boiling and thereby sterilizing milk in single portions for the use of infants. Marfan believes that milk heated in a double boiler, such as the Soxhlet apparatus, to 100° C. for forty minutes will remain sterile from four to five days if the conditions are favorable. If this is used within twenty-four hours, it may be considered practically sterile. The same physical and chemical changes are found in this milk which are found in any milk heated to or above 80° C. If rubber corks are used,

as in the Soxhlet apparatus, a disagreeable odor and taste may be imparted to the milk. Marfan's experiments show that the actual temperature of the milk never exceeds from 95° to 96° C.,* so that the casein ferments cannot be destroyed. (The slow development of the latter may be explained by the hermetic closure of the jars, which excludes all oxygen.—EDITORS.)

It is probable that the effect of a high temperature which alters the mode of coagulation of (sterilized) milk is favorable rather than unfavorable to its digestion. The only satisfactory test would be to feed a series of infants of like age and weight on sterilized milk and raw milk, the amounts of food being carefully estimated; in other words, to carry out metabolism experiments. The results of test-tube experiments are too unlike the actual conditions to be satisfactory. Marfan's practical experience leads him to the following conclusions: with good methods of purification by heat, accidents of feeding are much reduced in number, gain in weight is much more steady, and gastro-enteritis, especially in its severe forms, becomes less frequent.

Budin, in 1892, found that pure cow's milk, if sterilized, could be digested by the new-born infant. Since then this view has been corroborated by Chavanne, Variot, Comby, B. Lazard, Drapier, and Madame Brès (1896).

Marfan states that the avoidance of excessively high temperatures, the exclusion of air, and rapid after-cooling have served to diminish the changes brought about by sterilization, which are found only to a slight degree in the ordinary commercial sterilized milk sold in France. It is important that this milk should be used within a week, otherwise the fat-droplets will separate. Heating to 40° C. and a thorough shaking will restore the emulsion. Estimates made by the pharmacist of the Hôpital des Enfants Malades show that the

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* Johannessen[230] says that the temperature of the milk in the bottles of the Soxhlet apparatus rarely exceeds 96° C.

percentage of phosphoric acid in sterilized milk is practically always normal, provided the bottle is first thoroughly shaken. If the bottle is not disturbed, a layer of mucus is formed on the sides and bottom, containing from one-half to one-thirtieth of the total phosphoric acid present. Marfan does not consider that these facts constitute valid objections to the use of sterilized milk.

BIEDERT [7] approves of sterilization. The objection raised, that lactic acid bacteria are destroyed by this process, does not hold, since many of these organisms are already present in the mouth and stomach. The milk mixture should be put into separate bottles, sterilized, immediately cooled, and kept cool until ready for use. Since the majority of people are unable to carry out this process, simple boiling in a covered receptacle can be recommended, provided the milk is not afterwards disturbed.

Flügge has objected that the fat separates in large globules after sterilization. This can be remedied by shaking the bottles in a circular direction before use.

FENWICK [52] recommends sterilization when milk is liable to be contaminated; otherwise pasteurization is preferable.

THOMSON [147] advises sterilization for those who live in cities, as long as dairy methods are so imperfect. The milk must be sterilized while fresh. Pasteurization is not wholly satisfactory.

COMBY [62] considers it indispensable to boil or sterilize cow's milk for young infants, especially in cities, owing to the dangers of tuberculosis, aphthous fever, etc. He permits the use of pure milk only in exceptional cases, as in the country districts or where the cows react negatively to tuberculin. Sterilization prevents germ infection and causes molecular modification of the casein which renders it more assimilable for young infants.

VARIOT [151] believes the best method is to have the milk sterilized in gross at 115° C. at the dairy farms immediately after

milking. It is then hermetically sealed in quarter- and half-litre bottles. These are distributed with careful directions as to the size of the meals. He usually gives whole milk after one month; to those with weak digestion he gives it after the second or third month. Before that time milk should be diluted with from one-third to one-fourth its amount of water. Most of his cases so treated (eight hundred in all) did well. Scurvy was never observed and rickets but seldom; many of the infants, however, were constipated and anæmic.

Baginsky [6] thinks that the Soxhlet method gives the best practical results, although it does not completely sterilize the milk. Immediate cooling and use within two days are essential factors. Many children cannot digest milk so treated, however. He has never encountered scurvy following its use.

Troitsky.[141, 142] Sterilization probably produces some chemical changes in milk, but does not render it indigestible. Under present conditions we have no better substitute for mother's milk. Both sterilized and raw milk are good culture media, but germs grow less readily in the former. The bottle of sterilized milk may be opened once or twice without becoming infected, but each repetition increases the danger of contamination.

Koplik.[80, 81] Years of observation have not borne out the objection that milk is rendered more difficult of digestion by sterilization.

Starr.[133] Sterilized milk is especially useful on a long journey during the heated term and as a temporary change of diet for delicate children suffering from gastro-intestinal diseases.

Ashby and Wright [2] think that it is impossible to sterilize stale milk at the home. If the milk is fresh and clean, a temperature of from 70° to 75° C. is sufficient; otherwise it should be heated to 100° C. for half an hour.

F. Gernsheim.[67] Variations in the fat content of the separate bottles can be avoided only by thorough stirring and

shaking of the milk just before filling. If the milk is kept in a large vessel, it must be well stirred in a circular direction before pouring. Contamination with germs is not likely to occur if the bottles have previously been sterilized.

Objections to Sterilization.

CARSTENS, of Leipsic, at the seventieth meeting of the Society of German Naturalists and Physicians, in 1898, emphasized the importance of cleanliness in securing and handling milk, and the disadvantages following the use of sterilized milk (anæmia, rickets, and scurvy). If milk can be obtained clean and fresh, simple boiling for ten minutes is preferable to sterilization; otherwise, we sterilize for thirty minutes. The administration of sterilized milk exclusively beyond the ninth or tenth month is not to be recommended. He believes that a dilution of one to three is necessary only for small babies during the first month; after the second month we can use stronger concentrations.

VON STARCK, of Kiel,[150] expresses these views: 1. The prolonged and exclusive use of sterilized milk for infants leads in a considerable number of cases to disturbance of nutrition, showing itself as severe anæmia, rickets, scurvy, etc. 2. The uniformity of the diet is largely responsible for this, besides the physical and chemical changes produced by sterilization. 3. If clean raw milk cannot be obtained, the milk should be heated, to what degree and for how long depends on the circumstances of the individual case. 4. In certain conditions sterilization is necessary. 5. Fresh, clean boiled milk is the normal substitute for mother's milk, and gives as good results as sterilized milk without the disadvantages of the latter.

Eighty-four out of three hundred physicians in Schleswig-Holstein reported the occurrence of rickets, anæmia, retarded development, constipation, etc., resulting from the continued use of sterilized milk.

Dawson Williams, Bendix, Czerny, and von Stark, of Munich, believe that scurvy may result from the continued use of sterilized milk, and in 1895 Starr reported five cases of this disease in infants under two years, following its employment.

Holt says that infants fed on sterilized milk are apt to be constipated.

Monti [99] is convinced that the value of milk as an infant food is distinctly affected by sterilization, and that many disadvantages are connected with its use in infant feeding. Rickets, dyspepsia, and high-grade anæmias are apt to result.

J. Kingston Barton [15] thinks that scurvy will undoubtedly follow the use of completely sterilized milk, if no fresh food is administered at the same time.

H. Johnstone Campbell.[29] Scurvy and rickets often follow the use of sterilized milk. Since it is not well digested, the infant receives an insufficiency of food, especially of the fats and carbohydrates.

The American Pediatric Society has collected a total of three hundred and fifty-six cases of scurvy.[3] Out of this number, sixty-eight cases were fed solely on sterilized milk.

Jacobi [76] calls attention to the fact that, unless sterilization be complete, the resistant spores of bacteria may find a better opportunity for development, since the lactic acid ferments have been destroyed. The longer such milk is kept before it reaches the consumer the more dangerous it becomes. Cream separates from sterilized milk. Renk found that this separation occurs to a slight extent within one week of sterilization, and that later 43.5 per cent. of the cream was separated. Jacobi considers the question of chemical changes not yet definitely settled. The substitution of sterilized milk for mother's milk as the sole food for the infant is a mistake. Digestive disturbances and rickets are frequently due to its persistent use, and it appears to be, at least occasionally, a co-operative cause of scurvy.

We have found it convenient to place in tabulated form a list of the physical and chemical changes which are said to follow the process of sterilization.

A. Decomposition of lecithin and nuclein (Baginsky, von Starck, Biedert, Jacobi, Edlefsen), also of nucleon (Edlefsen).

B. Organic phosphorus is diminished and inorganic phosphorus increased in amount (Baginsky, 1894).

C. The greater part of the phosphates are rendered insoluble (Monti, Dawson Williams, H. Johnstone Campbell).

D. Precipitation of the calcium and magnesium salts (Ashby and Wright, Jacobi, Dawson Williams, H. Johnstone Campbell).

E. The greater part of the carbon dioxide is driven off (Johannessen, Dawson Williams, H. Johnstone Campbell).

F. Normal lactic acid fermentation is prevented (Biedert).

G. Lactose is completely destroyed (Leeds, Baginsky). Duclaux denies this. Johannessen states that it does not occur below 110° C.

H. "Caramelization" of certain portions of the lactose (Holt, Renk, Monti, Jacobi, Carpenter).

I. The fat emulsion is partially destroyed or rendered imperfect by the coalescence of the fat-globules (Renk, Biedert, Monti, Ashby and Wright, Jacobi, J. Lewis Smith, H. Johnstone Campbell, Johannessen).

J. Separation of the serum-albumin begins at 75° C. and increases as the temperature is raised (Renk, Koplik, Cautley, Jacobi, Freeman, J. Lewis Smith, H. Johnstone Campbell).

K. Casein is rendered less easy of coagulation by rennet (Baginsky, Leeds, Holt, Koplik, J. Lewis Smith, H. Johnstone Campbell).

L. Casein is slowly and imperfectly acted upon by pepsin and pancreatin (Leeds, Holt, Jacobi, H. Johnstone Campbell). Leeds says that the proteid substances become attached to the

fat-globules and probably hinder to some extent fat assimilation.

M. Peptones and toxins can be found after prolonged sterilization (von Starck). They are said to be produced by the action of chlorides on casein (A. Christiaens, *L'Union Pharmaceutique,* August 15, 1894, cited by Marfan).

N. The starch-liquefying ferment is destroyed and coagulated (Leeds, J. Lewis Smith).

O. The taste is rendered objectionable (Renk, Holt, Cautley, H. Johnstone Campbell). Marfan considers this a small objection, as the infant's taste is poorly developed.

Boiling.

Marfan.[105] Milk boils at about 101° C. It rises before boiling, beginning at 75° C., according to Comby, and 85° C., according to Gautrelet. It is necessary to break up the skim on the surface of the milk and to keep it on the fire until large bubbles appear. Milk boiled from three to four minutes does not contain lactic ferments or pathogenic germs, but it will not keep for any length of time, because the spores of the casein ferments are not destroyed. The skim is composed of casein, but, since the latter is present to excess in cow's milk, Marfan does not consider this objectionable. The increase in density to which Duclaux and Crolas have called attention is too insignificant to be of any consequence. If milk can be boiled directly after milking, and used the same day, it may be employed without hesitation.

Jacobi[76] calls attention to the fact that pasteurization and sterilization are logical developments of his plan of boiling milk which he advocated forty years ago. He asserts that boiling expels air. The following bacteria are destroyed: the bacilli of typhoid fever, diphtheria, tuberculosis, cholera, the oïdium lactis. Some varieties of proteus and most of the bacilli coli communis are rendered innocuous; the hay bacillus and the bacillus butyricus are not destroyed. Jacobi thinks that

the daily home sterilization of milk is far preferable to the risky purchase from wholesale dealers who cannot guarantee, as they cannot know, the condition of their wares.

Sommerfeld.[128] Flügge advises for practical work to boil the milk for a short time (which destroys most of the pathogenic germs), then to cool it rapidly and protect it from air infection. Cooling hinders or checks the development of dangerous forms, such as the peptonizing and anaërobic bacteria. He thinks that Soxhlet's method requires too long boiling and does not lay sufficient stress on rapid cooling. Prolonged heating causes physical and chemical changes in milk.

Czerny [34] advises boiling for ten minutes.

Henoch [71] advises that only pure milk should be used and that it should be boiled for half an hour.

Bendix [10] disapproves of boiling for more than half an hour, since change of taste and other deleterious alterations may be produced. Milk so prepared should be used within from twenty-four to thirty-six hours at the longest.

Objections to Boiling.

At the Moscow Congress, in 1897, Schlossmann asserted that boiling milk caused alterations in the fat, albumins, and phosphorus-containing substances.

Chemical Changes in Sterilized Milk.

Holt.[69] The changes in milk resulting from the application of heat begin at 180° F. and become more marked the higher the temperature and the longer it is maintained. Sterilization should be done at the dairy. Its value consists in the prevention, not the cure, of disease; it is unnecessary if pure milk can be freshly obtained.

Richmond.[120] The most marked characteristic distinguishing sterilized from new milk is the state in which the albumin exists. In milk which has been heated, coagulation does not occur; but if it is acidified or saturated with magnesium sulphate,

the albumin separates with the casein. It appears to be changed from a soluble to a colloidal form. Not more than 0.1 per cent. of albumin is found in sterilized milk in a soluble form.

Cream rises extremely slowly in sterilized milk; in six hours only one-tenth of the amount is present that we should have found in raw milk. In twenty-four hours the bulk of the cream will rise, but the total quantity will be less than that from the same amount of raw milk, while the fat percentage will be forty as against thirty in fresh cream.

Partial freezing of milk causes no changes in any of the constituents except the water. Vieth found that exposure of large quantities of milk to —10° C. for three hours caused it to freeze, except in the centre. The ice consisted of two layers, one of cream and the other of skimmed milk. The cream contained 19.23 per cent. fat, 2.64 per cent. proteids, 3.33 per cent. lactose, and 0.52 per cent. ash. The milk contained 0.68 per cent. fat, 2.80 per cent. proteids, 3.95 per cent. lactose, and 0.60 per cent. ash. The liquid portion contained 5.17 per cent. fat, 5.38 per cent. proteids, 7.77 per cent. lactose, and 1.18 per cent. ash. These figures show that milk cannot be frozen in blocks, from which pieces can be cut off and melted for use, without its composition being modified to a serious extent.

At 70° C. albumin undergoes change. It is not precipitated, but is converted into a form which is precipitated by acid magnesium sulphate and other precipitants of casein. Heating above 70° C. alters the taste and smell of milk. At about 80° C. certain organized principles, the nature of which is not fully known, undergo a change. When the temperature nears 100° C., calcium citrate is deposited. By keeping at this temperature for some time, slight oxidation sets in with the production of slight traces of formic acid and marked reduction of the rotatory power of lactose; a brown color is produced at the same time. A deposition of salt and perhaps of albumin also takes place in the fat-globules, which

increases their mean density, causing them to rise slowly to the surface when the milk is afterwards cooled. During the heating the fat-globules are expanding, and may sometimes coalesce. It is not known how far the heating of milk affects its digestibility. Milk which has been heated is curdled less readily by rennet than fresh milk, but there are good grounds for the view that this is due to the deposition of calcium salts rather than to any change in the casein. It has been asserted that sterilized or boiled milk is digested more easily than raw milk, but this may be due to the fact that it does not curdle so easily in the stomach and does not produce so firm a clot.

The Artificial Digestion of Raw and Sterilized Milk.

MICHEL.[101] The author carried out experiments in Budin's laboratory with the artificial digestion of raw and sterilized milk: (1) with hydrochloric acid and pepsin; (2) with pancreatin in neutral or alkaline medium; (3) digestion of the curd produced by the action of the lab-ferment with pepsin and hydrochloric acid; (4) digestion of the curd so produced by pancreatin; (5) complex digestive processes with lab, hydrochloric acid, pepsin, and pancreatin.

In his experiments the polarimeter was used to estimate the amount of peptones. The basis employed in the estimations was the ratio of the peptones to the total nitrogen. One gramme of nitrogen represents 6.41 grammes of peptones approximately. The Kjeldahl method was used.

I. Digestion was maintained in the incubator for nearly eight hours at 40° C. Raw milk furnished 18.75 grammes of peptones; sterilized at 115° C., 17.53 grammes, the former showing somewhat more rapid digestion.

II. Digestion for five hours gave 21.76 grammes for raw milk and 24.64 grammes when the milk was sterilized at 115° C.

III. Digestion in the incubator for three and a half hours at 40° C. gave 7.57 grammes for raw milk and 10.72 grammes

for sterilized milk. When the digestion was kept up for eight and a half hours, raw milk furnished 14.316 and sterilized milk twelve grammes of peptones.

IV. The curd is digested much more rapidly by pancreatin when sterilized milk is administered (28.22 grammes) than when we give raw milk (13.12 grammes).

V. The digestion of raw milk by lab-ferment, pepsin, and hydrochloric acid is slower in the first three hours than that of sterilized milk (9.59 grammes as against 11.32 grammes); at the end of six and nine hours it is more rapid, giving at the latter period 16.64 grammes as against 14.91 grammes. Further digestion with artificial pancreatic juice for six hours gave 21.76 grammes of peptones for raw milk and 24.57 grammes for sterilized milk.

Digestion of the Lactalbumins.

[101] Sterilized milk contains almost no coagulated albumin; but in contact with the acid gastric juice the albumin of sterilized milk precipitates, while that of raw milk remains in solution. This albumin, whether in solution or not, is of long and difficult peptic digestion. The total of these experiments shows that sterilization does not injure, but rather increases the digestibility of the milk albuminoids. (? EDITORS.)

Filtration through Cotton, and Centrifugation.

Marfan believes that filtration through cotton, to be efficacious, must slightly alter the constitution of the milk. If germs cannot pass, neither can all of the milk constituents. If the composition is not modified, neither is the bacterial find.

Seibert has proposed filtration through moist cotton to free milk from germs, stating that the milk was not altered. Variot found this to be the case, but that the impurities passed through as well. Heat is the only satisfactory germicide.

Seibert (*Archives of Pediatrics,* July, 1894) asserted that simple filtration through a half-inch layer of compressed absorbent cotton reduced the number of bacteria from one-half to one-fourth the original amount. Kiliani confirmed his results. Biedert recommends centrifugation and filtering to remove dirt.

Schoenlein found that after centrifugation, and when cream forms by the gravity process, the majority of the bacteria are found in the cream, very few in the dirt which is thrown out, and the remainder in the skimmed milk.

CHAPTER X.

WEIGHT AND GROWTH OF THE INFANT.

MONTI.[99] The body weight of a child born at term varies from two thousand five hundred to five thousand grammes, seldom exceeding the latter figures; three kilogrammes may be considered the average. Twins usually weigh only from two thousand to two thousand four hundred grammes; children of primiparæ generally from one hundred and seventy to one hundred and ninety grammes less than those of multiparæ. Within a few hours of birth a loss of weight occurs, due to the evacuation of meconium (from sixty to ninety grammes) and the passage of urine (from ten to fifteen grammes), evaporation from the lungs and skin, and to the deficient intake of food during the first days of life. This diminution continues for two or three days, and is made up within from five to eight days. In the case of healthy infants at the breast it amounts to from one-fourth to one-sixteenth of the body weight, or on the average to from one hundred and seventy to two hundred and twenty-two grammes. In the case of the artificially fed child the loss in weight may last one or two days longer. The poorer the development or the less the body weight of an infant the longer will be the loss and the slower its equalization. In premature infants this is especially noticeable. Such may not regain their weight before the third or fourth week. Premature infants who are artificially fed may lose one-tenth of their original weight, and not regain it in five or six weeks; they should therefore, whenever practicable, be given breast-milk.

The increase in weight of infants at the breast during the first year follows one of three types.

I. In a large series of cases the increase in weight proceeds regularly from month to month; this was first observed by Quetelet and Bouchaud.

Age.	Daily increase. Grammes.	Monthly increase. Grammes.	Body weight in grammes. Original weight 3250 grammes.
One month..................	25	750	4000
Two months	23	700	4700
Three months	22	650	5350
Four months................	20	600	5950
Five months	18	550	6500
Six months	17	500	7000
Seven months	15	450	7450
Eight months	13	400	7850
Nine months................	12	350	8200
Ten months.................	10	300	8500
Eleven months	8	250	8750
Twelve months..............	6	200	8950

II. Those cases where the increase in weight is progressive, diminishing from month to month, but in which the increase in weight is much greater during the first four months and smaller in the last months than in the preceding type.

FLEISCHMANN'S TABLE. Age.	Daily increase. Grammes.	Monthly increase. Grammes.	Body weight at birth 3500 grammes.
One month	35	1050	4550
Two months	32	960	5510
Three months...........	28	840	6350
Four months	22	660	7010
Five months............	18	550	7560
Six months	14	420	7980
Seven months...........	12	360	8340
Eight months...........	10	300	8640
Nine months	10	300	8940
Ten months	9	270	9210
Eleven months..........	8	240	9450
Twelve months	6	180	9640

III. In this class belong those cases where the body weight does not increase regularly, but by fits and starts, and in which the greatest increase frequently occurs in the second or the fourth month and diminishes after that time.

The following table is taken from Hähner, the child weighing three thousand one hundred grammes:

Age.	Daily increase. Grammes.	Monthly increase. Grammes.	Body weight. Grammes.
One month	24.5	735	3835
Two months	36.5	1095	4930
Three months	20.5	610	5540
Four months	15.6	470	6010
Five months	22.3	670	6680
Six months	10.8	325	7005
Seven months	22.5	675	7680
Eight months	14.0	420	8100
Nine months	9.0	270	8370
Ten months	10.3	310	8680
Eleven months	16.3	490	9170
Twelve months	10.0	300	9470

Monti, on the basis of his own experience, considers that the first type is characteristic of children who have the normal average original weight and are fed regularly. The second type occurs in children who have higher original weight and are fed plentifully. The third type seems to occur only where the child has been overfed. The original weight may be normal or above it.

From this it appears that the body weight of a child doubles in the first five months and triples at the end of the first year. The data here presented are of course only schematic. The conditions affecting the individual child, its hygienic surroundings, the diet of the mother, correct or incorrect observance

of rules of feeding, etc., will all give a different weight-curve, which, notwithstanding the above conditions, must be considered normal. Camerer gives, on the basis of weighings of fifty-seven children at the breast, with an original weight of three thousand four hundred and fifty grammes and over, the following tables, representing the weight in grammes at the end of the following weeks.

I.

At birth	1	2	4	8	12	16	20	weeks
3450	3400	3490	3890	4680	5410	6090	6650	grammes
24	28	32	36	40	44	48	52	weeks
7130	7570	7990	8400	8580	9020	9300	9890	grammes

II. Daily Increase in Grammes.

1–2	2–4	4–8	8–12	12–16	16–20	weeks
3	29	28	26	24	20	grammes
20–24	24–28	28–32	32–36	36–40	40–52	weeks
17	15	15	14	7	15	grammes

In children whose weight at birth is subnormal the daily gain is usually less, and it approximates that of normal children only when it has regained the normal height corresponding to a child of that age.

Fleischmann was the first to notice the constant rise and fall in body weight; Vierordt and Malling-Hansen have confirmed Fleischmann's observations. Monti is also of the opinion that one must not assume for every child during the first year a steady increase in weight. The conditions of the day and year, the hygienic surroundings, the mother's diet, and anything affecting the child's environment must be considered in order to avoid error.

The increase in weight is quite different in children on mixed feeding. They show variations and irregularities which appear in the following table:

Mixed Feeding.

Age.	Physiological daily gain, types I. and II. Grammes.	Anomalous daily gain. Grammes.	Physiological monthly gain, types I. and II. Grammes.	Anomalous monthly gain. Grammes.	Physiological gain since birth. Grammes.	Anomalous gain since birth. Grammes.
One month	25–35	12–13	750–1050	375–1090	750–1050	375–390
Two months	23–32	20–29	690–960	600–870	1440–2010	975–1260
Three months	22–28	25–27	660–840	750–810	2100–2850	1725–2070
Four months................	20–22	18–24	600–660	540–720	2700–3510	2265–2790
Five months................	18	7–19	540	210–570	3240–4050	2475–3360
Six months	14–17	10–20	420–540	300–600	3660–4560	2775–3960
Seven months..............	12–15	12–15	360–450	360–450	4020–5010	3135–4410
Eight months...............	10–13	13–18	300–390	390–540	4320–5400	3525–4950
Nine months................	10–12	10–22	300–360	300–666	4620–5760	3825–5610
Ten months	9–10	5–18	270–300	150–540	4890–6060	3975–6150
Eleven months..............	8	5–10	240	150–300	5130–6300	4125–6450
Twelve months	6	6–10	180	180–300	5310–6480	4305–6750

In artificially fed children the gain in weight during the first year is usually less than in children at the breast or in those getting mixed feeding.

According to the condition of the digestive tract and the degree of absorption, the gain in weight of artificially fed infants is subject to manifold variations and disturbances. Monti's personal experience leads him to conclude that in artificially fed children the gain is seldom normal or regular.

Russow has found that the weight of the hand-fed infant is not tripled before its second year. This difference is also observed in the later years of life, so that breast-fed infants in their fourth year weigh, on the average, two thousand grammes more than artificially fed infants. The same author gives the following table of the average gain in weight of children fed on cow's milk plus starchy foods: fifteen days, 2900 grammes; three months, 4089 grammes; six months, 4744 grammes; eight months, 5254 grammes; twelve months, 6128 grammes; two years, 7430 grammes; four years, twelve kilogrammes; eight years, eighteen and three-tenths kilogrammes.

Camerer states that artificially fed children are backward in their development during the first half-year and weigh about one kilogramme less than breast-fed children of the same age. Monti takes exception to Camerer's statement that at the end of the first year hand-fed children have an equal weight with breast-fed children. He thinks that this occurs only exceptionally.

Weighings should be made every eight days at a fixed hour during the first year. Daily weighings give uncertain results.

Cautley.[38] Three kilogrammes (six and a half pounds) is a fair average weight at birth, though often exceeded. There is a decided loss in weight during the first few days of life, which has been estimated by Haake, Quetelet, and Winckel at about half a pound. The prolonged presence of

colostrum in mother's milk may induce a loss in infants who would otherwise gain. The passage of meconium and urine, the excretion of water by the skin and the expired air, the falling off of the cord, and the lack of food, all account for what may be termed the physiological loss, although this does not invariably occur.

Stated roughly, the initial weight is doubled at five months and trebled at fifteen months. Rotch gives the following figures based on an original weight of from three thousand to four thousand grammes. From birth to five months the average gain per day will be twenty to thirty grammes, from five to twelve months the average gain per day will be ten to twenty grammes, and at one year a child ought to weigh nine and a half kilogrammes (20.9 pounds). Cautley deduces an average table from those of Sutils, Schmid-Monnard, Hähner, Rotch, and others. He estimates thirteen months of twenty-eight days each; the figures represent the weekly gain:

	Ounces.		Ounces.
One month	6	Eight months	3½
Two months	7	Nine months	2½
Three months	6	Ten months	2½
Four months	5½	Eleven months	2
Five months	5	Twelve months	2
Six months	4½	Thirteen months	1½
Seven months	4		

This amounts to a gain of about six ounces a week during the first three months, five ounces a week for the second three months, three ounces a week for the third three months, and two ounces a week for the remainder of the year.

The increase of weight does not take place with such absolute regularity as indicated in the table, either in bottle-fed or breast-fed infants. To a certain extent the rate of gain is affected by the period of the year, attaining its maximum

between July and October. Sunlight and fresh air are also beneficial and increase the rate of growth. The gain is not invariably proportionate to the initial weight. Infants abnormally small at birth sometimes gain with much greater rapidity than those of a much larger initial weight.

J. P. Crozer Griffith,[172] in an article in the *New York Medical Journal* for March 4, 1899, mentions the difficulties encountered in calculating the normal variations in weight during the first two years of life: the influence of feeding, the amount of food, defecation and urination, perspiration, and even the ordinary metabolic changes occurring during sleep. The child's weight is distinctly greater at night than in the morning. It seems impossible to apply the precise algebraic rule of Raudnitz, based on a given age. The best that can be done is to determine the general average in a large number of cases and to represent it graphically in the form of a weight-chart.

In generalizing methods a number of infants of a certain age are weighed. Another group, perhaps differing in number and age, are also weighed. The results are apt to be deceptive and do not represent true or normal conditions.

"In Lorey's investigations, weighings of five hundred and sixty-five children were made by this method. In spite of this large number, it is quite evident that the irregularities which his weight-curves show, especially in the second year, do not represent the actual condition to be expected in the average child. In the combined curve for both sexes, for the second year, it appears that children at twenty-one months weigh less than they do at twenty months, and again less at twenty-four than they do at twenty-three months. This certainly does not represent the true state of the case. Lorey makes no claim that his figures yield any statistical results, although based on so many cases.

"The individualizing method is better. The weighings of one child are recorded at frequent and regular intervals

CHART I.

WEIGHT IN FIRST 10 DAYS

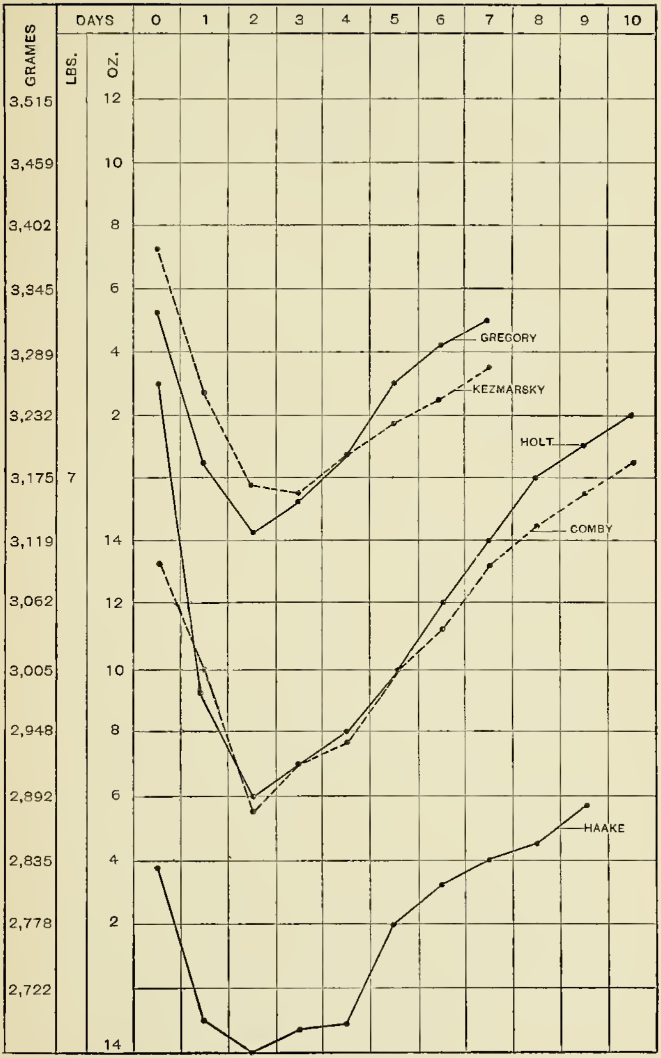
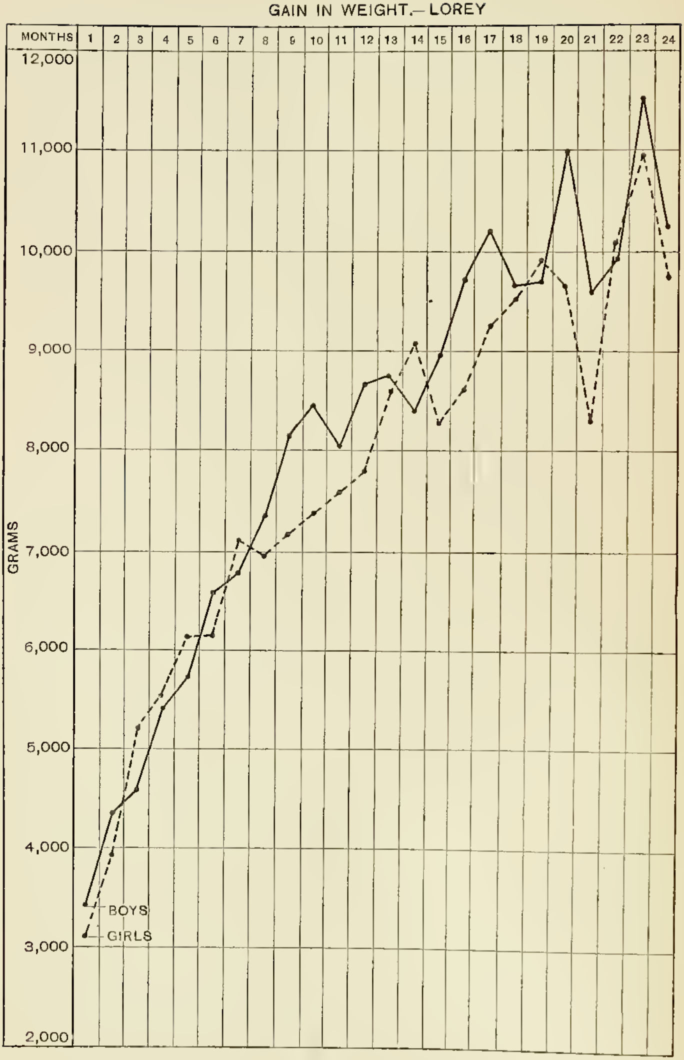


CHART II.


GAIN IN WEIGHT.—LOREY
MONTHS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
GRAMS
BOYS
GIRLS

throughout its infant life, and comparison is made with a large number of similar records of individual cases. The mean weights and the average rate of increase for different periods of the child's life can readily be computed.

"It has been of interest to me to compare the various tabulated observations which have been made in the effort to determine the growth of the child during the first two years of life. Perhaps the oldest and one of the most quoted tables of growth is that of Quetelet, but this is more ideal than actual, and, as plotted by Fleischmann, gives a straight line rather than the curve which represents the actual condition of affairs as now understood. The straight line results from the assumption that the rate of growth is the same for all periods of the first year.

"A second much-quoted estimation is that of Bouchaud. Although his observations were made by the individualizing method, he has rounded off his figures to such an extent that his final table of growth is much too schematic. The plotted curve is, however, a more accurate representation than that of Quetelet, although it gives a rate of growth lower than may be expected of the average healthy breast-fed infant.

"A table of weight, constructed by Fleischmann by the individualizing method applied to fifteen breast-fed children, is often referred to. I have plotted the curve derived from these figures in Chart II. It shows the rapidity of growth of the first months and the diminishing rate during the succeeding months.

"Recently a useful curve has been published by Holt, constructed apparently by the individualizing plan.

"One of the most careful studies of the subject is that of Camerer. This observer has followed by the individualizing method the rate of growth of a large number of children during the first year of life, has studied the similar observations of Fleischmann, Vierordt, and others, and has published several tables and curves which, on the whole, appear

to be the most valuable we yet possess. Attention has been paid to the variations in initial weight and influence of these upon the later weights, and also to the nature of the food, whether human milk or cow's milk. Even Camerer's curves, however, have certain irregularities which prevent their being taken as types,—for which, indeed, they are not intended. In Chart II. I have plotted the curve of his figures for breast-fed children with an initial weight of over seven hundred and fifty grammes (six pounds and one ounce). Camerer also gives some estimations of the rate of growth during the second year (Chart II.). Another observation upon growth in the second year is that of Lorey, already referred to. In Chart II. I have combined his chart for boys and girls respectively during the second year, thus eliminating some of the irregularities. In all the curves represented in Chart II. all figures originally in the metric system have been reduced to avoirdupois weight for the convenience of comparison.

"The following weight-chart (IV.) has been constructed in the effort to represent as nearly as possible the average rate of growth of healthy breast-fed children. Although to a certain extent schematic, as any averaging chart of this nature must necessarily be, it is, I think, as accurate as can be expected of any one suited for practical purposes. It has been made after a careful study of most of the available published data, although it follows Camerer's curve more nearly than any other.

"The fact that it is so often necessary to record the weight of poorly developed children during the second year necessitated the representing in this chart of the continuous growth during the first two years of life. The line passing obliquely through it represents, of course, the rate of growth of healthy breast-fed children. Bottle-fed babies, as a class, fall below this weight, yet by no means necessarily so. There is also some difference in weight depending upon sex, boys being generally heavier than girls. This difference may, however,

be ignored in this connection. Each horizontal line represents a difference of four ounces. A gain of two ounces or even less can be indicated by marking between the lines. The weight should be taken weekly and recorded by dots connected by a line, as in a temperature-chart. For convenience, the figures at the top show not only the weeks, but the months as well. In order to prevent the chart from becoming of an unmanageable size, the portion for the second year—since this will be needed less frequently—has been narrowed in such a way that the space for four weeks is of the same breadth as that for two weeks during the first year. This necessarily distorts the proper position of the plotted curve, and gives the erroneous impression to the eye that the child grows as rapidly during the second year as during the first. It is evident that if the spaces for the years were of equal breadth, the curve for the second year would be very much nearer a horizontal line. For practical purposes this distortion of the curve is of no moment, since its actual relation to the figures is unaltered.

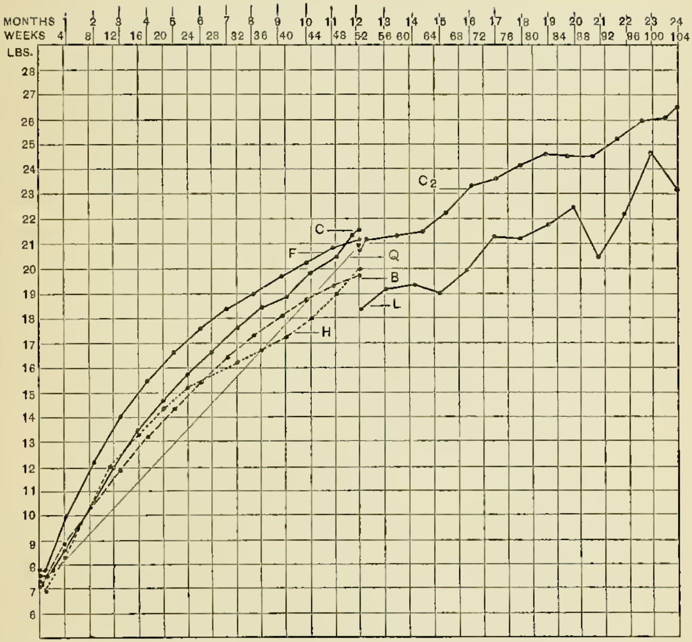
"There are a few matters remaining to which brief reference must still be made. First, the birth-weight assumed (seven and three-fourths pounds) is somewhat more than that given by many writers, yet it agrees practically with the statistics of Fleischmann, as also with those of Camerer for many of his cases. Should a child at birth weigh much less than this, it is to be expected that the rate of growth will be very much the same. This will give a curve slightly below that of the chart. But a child who weighs over seven pounds at birth may be expected to reach the full normal weight by the age of one year.

"Then as to the loss in weight which the child suffers after birth before its regular gain begins. Although this does not necessarily take place, yet its occurrence is the rule and may be considered physiological. This was shown by the interesting experiments of Ingersley, who allowed sixteen chil-

dren immediately after birth to be suckled regularly by women who had been confined a few days before. The remarkable fact was noticed that the children showed not only a greater but a more prolonged loss of weight than the average.

"There have been various estimations made of the degree and duration of loss. Some of these I have depicted in Chart III., including the observations of Gregory, Kezmarsky, Holt, Comby, and Haake. In all cases statistics in the metric system or, in the case of Haake, in the old German system of weights have been changed into pounds and ounces avoirdupois. The curves of Gregory and Kezmarsky, it will be noticed, run much together. The first was based upon observations made on thirty-three and the second on thirty-two healthy breast-fed children. Kezmarsky explains the greater duration of loss in his cases and the slower gain, as compared with Gregory's, on the ground that the children under his care were not nursed with the regularity which was desirable. In Gregory's they have nearly regained the normal weight by the seventh day; Kezmarsky's fall much short of this. These two curves are largely in accord with the observations of Winckel, and seem to represent the experience of most investigators. The curve representing the table of Comby seems to be largely schematic. I cannot find on what actual observations it is based. The curve of Holt represents his experience with a hundred healthy breast-fed children. It differs from the others in the greater degree of loss of weight, which equals ten ounces (two hundred and eighty-four grammes). This, however, is in accord with the observations of Townsend on the records of two hundred and thirty-one breast-fed children in the Boston Lying-in Hospital. Here the average loss was two hundred and seventy-nine grammes (9.8 ounces). I presume, however, that children suffering from illnesses were not excluded in making the computation. The observations of Haake on one hundred healthy breast-fed children, as shown in the curve, not only give a loss which

CHART III.



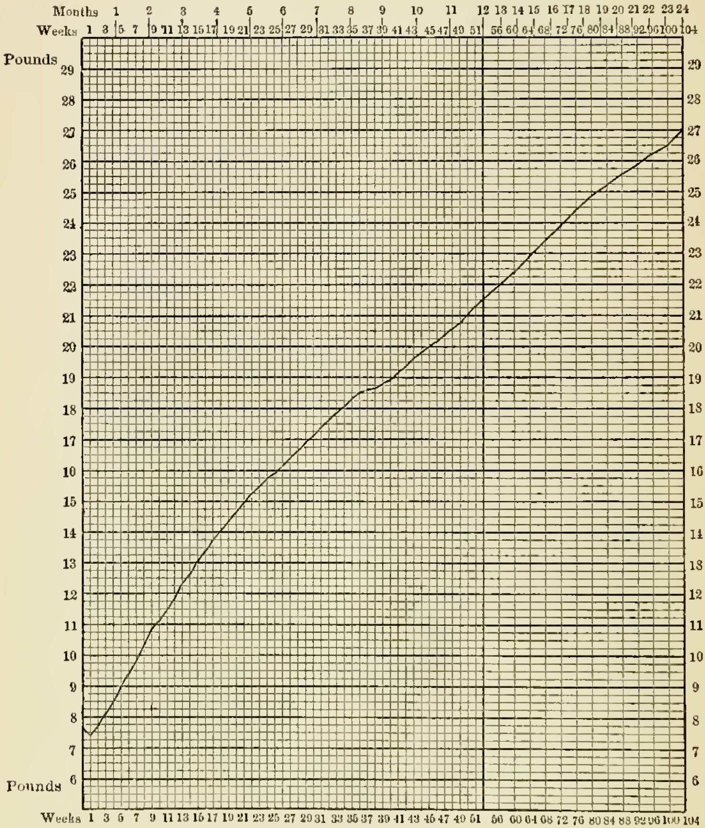
Weight-curves of C—Camerer. C_2—Camerer, second year. F—Fleischmann. H—Holt. L—Lorey. B—Bouchaud. Q—Quetelet.

CHART IV.

INFANT'S WEIGHT-CHART.

(Designed by J. P. Crozer Griffith, M.D., Clinical Professor of Diseases of Children in the University of Pennsylvania.)

Name..   *Date of birth*..



is less than that usually accepted as the common one, being but a hundred and sixty-three grammes (5.75 ounces)', but also an initial weight lower than the average.

"According to Fleischmann, who has made a careful study of various writers' estimations, the average total loss equals two hundred and twenty-two grammes (7.8 ounces). The duration of loss is from two to three days, and sometimes longer. The total loss equals about one-fourteenth or one-fifteenth of the initial body weight. Increase in weight begins on the second to the fourth day, but the original weight is seldom regained before the eighth or the ninth day or even not before the tenth day. Chart IV. shows the approximate loss existing at the end of the first week, but not the greater loss which has taken place before this date.

"Lastly, the variation in the weight-curve of any infant which a weight-chart will show must be borne in mind. Not only will there be a variation dependent upon the fulness of the stomach, bladder, and bowels, as already stated, but there is a variation which does not rest upon these factors and yet which cannot be called pathological. For instance, it not infrequently happens that a baby goes, it may be, a week without a gain in weight, or even shows a loss, and yet cannot be called ill. Yet such a condition should always arouse watchfulness.

"The value of the systematic recordings of an infant's weight scarcely needs to be emphasized. Every physician especially interested in diseases of children fully recognizes it, for he knows that often a failure to gain, even before the child shows to the eye any ailment whatever, may be the sign that some form of illness is present or that the child is underfed. The weight-chart is even more valuable than the temperature-chart in the case of infants. The weighing, too, is such a simple matter that there is no excuse for a failure to have it carried out by the mother at least once a week, and where a change in the method of feeding is being made, twice a

week. Good spring scales showing ounces are not expensive, or a steelyard or ordinary kitchen scales with weights will answer; but best are some of the standing spring scales fitted with an oblong basket or a scoop, and which are to be devoted solely to the weighing of the baby.

"It is of course understood that the weight recorded is that of the child undressed. If undressing at every weighing is inconvenient, the child may be weighed when dressed and then when undressed, and the weight of the clothes deducted. At subsequent weighings, then, it is only necessary to see that the clothing is exactly similar, and undressing will not be required."

Metabolism.

Cautley.[38] "The child requires more food in proportion to its body weight than the adult. The relationship of the different constituents of its diet to one another also varies because of the extra need of heat-producing food during the early months of life, to counterbalance the deficient heat production from lack of muscular energy and the greater loss of heat by the skin proportionately to the bulk of the body.

"Practically all foods may be considered to consist of five proximate principles: water, proteids, carbohydrates, fats, and salts.

"**Water.**—Though water is not primarily a source of energy nor nutritious in the ordinary sense of the word, it is nevertheless essential to life and constitutes more than half the entire body weight. Physiological activity of the cell depends upon a due supply of water. Proportionately to its weight, the infant requires much more than the adult; the relationship of the body surface to the body weight being considerably greater, therefore the loss of moisture by the skin is more in proportion.

"To a large extent water assists in digestion; it increases the secretion of pepsin and hydrochloric acid (Jacobi) and thus aids in proteid digestion; it is of great value as a solvent

and diluent of food substances and thus assists in absorption from the alimentary canal; it promotes the activity of the circulation of fluids, increases cell metabolism, and aids elimination; as a diluent of the intestinal contents it helps to prevent constipation.

"**Proteid** is the form of food in which nitrogen is supplied to the body. Nitrogenous matter is essential to the structure of protoplasm and enters into the structure of every cell. All the tissues of the body are formed by cells or modifications of cells, and consequently the child requires even more proteid, in proportion to its weight, than the adult, who has only to maintain equilibrium of tissue, whereas the infant has to provide for the building up of new tissue. An adult man of sixty-seven kilogrammes weight requires about a hundred grammes of proteid daily. An infant of 6.7 kilogrammes (the weight of an infant about six months old) takes one thousand grammes of milk daily, containing twenty grammes of proteid; much more proportionately than the adult. So, too, the growing child requires a free supply of proteid food, more proportionately than the adult, and yet very commonly gets less.

"Animal proteids are more digestible than vegetable proteids, and, as a rule, the more they are altered by cooking the more difficult of digestion they become. The chief animal proteids are the myosin of meat, the casein and lactalbumin of milk, and the various proteids of blood. All the proteids taken into the stomach are not necessarily digested and assimilated; even in an infant at the breast a considerable proportion of the proteids may be found in the fæces.

"When the proteids of the food are deficient, the child becomes anæmic, languid, debilitated, and short of breath on exertion. The muscles are soft and flabby and the child ceases to grow. Too great a proportion of proteids, on the other hand, leads to indigestion, colic, and constipation, especially when the casein is in excess.

"**Fat.**—The two great food-stuffs for the production of

heat are the fats and the carbohydrates, and of the two the fat is more valuable by virtue of the large amount of carbon which it contains. Fats are much poorer in oxygen and richer in carbon and hydrogen than the carbohydrates, and therefore their heat value is proportionately greater. Heat is essential to life, and all the vital processes are more active at the temperature of the body than at a lower temperature. This is more especially the case with the muscular and nervous systems. Although we have no proof that the fat in the tissues is formed from the fat taken in as food, it is well known that the fat stored up is soon drawn upon if the food is deficient, and hence the tissues may suffer indirectly. An infant of 6.7 kilogrammes takes in its milk forty grammes of fat, whereas an adult weighing ten times as much does not require more than one hundred grammes. The reason for this is that the infant cannot maintain its bodily temperature by exercise in the same way as the adult.

"Attempts have been made to remedy deficiency of fat in the infant's diet by the addition of carbohydrate food. Such a substitution is theoretically sound if fat is regarded as a source of heat only, and the proportion of additional carbohydrate required for this purpose can readily be calculated. Clinical results prove, however, that such a substitution is unsatisfactory, and that carbohydrates cannot replace fat to the advantage of the child. The best evidence of this is the prevalence of rickets among infants brought up on sweetened condensed milk.

"Artificial mixtures, as usually ordered, rarely contain such an excess of fat as to cause gastro-intestinal disturbances. Such results do occasionally occur in infants brought up at the breast where the mother's milk contains abnormally high percentages of fat. Generally at the same time there is an excessive proportion of proteids, so that it is difficult to ascertain to which excess the digestive disturbance is due.

"Too free an administration of fat in the food may give

rise to a variety of diarrhœa described by the Germans as 'fat diarrhœa,' and characterized by the presence of a large quantity of fat in the stools. It is usually associated with simple intestinal catarrh.

"**Sugar.**—Carbohydrates are of value for the production of heat and as a source of muscular energy. The infant weighing 6.7 kilogrammes takes about seventy grammes of carbohydrate in its milk; the adult of ten times the weight requires about two hundred and forty grammes and more in proportion to the amount of muscular work he performs.

"Infants at the breast practically never suffer from deficiency of carbohydrate food, the percentage in human milk varying within comparatively small limits; in artificial feeding there is more commonly an excess.

"Nearly all the patent foods and condensed milk on the market contain an excess of carbohydrates, generally in the form of starch or cane-sugar. Almost all the infants fed upon these foods become fat, flabby, unwieldy, and rachitic. Intestinal disturbances are also frequently induced.

"**Salts.**—Bunge was the first to establish the remarkable fact that the percentages of salts in the ash of the new-born animal are practically the same as the percentages of ash in mother's milk. Certain exceptions are noticeable and important. The ash of the milk contains more potassium and less sodium salts, which may be explained by the fact that, as the animal grows, there is a relative increase in the muscles which are rich in potassium and a diminution in the cartilages which are rich in sodium.

"Another important difference is the percentage of iron. The proportion of iron in the ash of the new-born animal is very much greater than in the ash of mother's milk. The latter deficiency is counteracted by the young animal storing up iron in its liver previous to its birth. Bunge has found that the proportion of iron in the ash of animals of the same litter diminishes with the increase in the growth of the ani-

mal, showing that this previously stored-up iron is required to make up for the deficiency of iron in the mother's milk.

"**Sodium Chloride.**—Cow's milk contains so much more sodium chloride than mother's milk that it is not necessary to add common salt to cow's milk in artificial feeding. [The analyses of Harrington and Kinnicutt and Söldner give contrary results.—EDITORS.] The addition of salt, however, has some advantages. It acts as a stimulant to the appetite and increases the secretion of hydrochloric acid, thus assisting in digestion. It aids in the solution of globulins in the blood; this group of proteids being insoluble in distilled water, but soluble in dilute alkaline solutions. When added to milk, salt diminishes its coagulability with rennet ferment and gastric juice, and may therefore be of advantage in feeding infants with weak digestions.

"It is a curious fact that all carnivorous animals require no additional salt with their food. Herbivorous animals take a considerable quantity of it, in proportion to the amount of vegetable food ingested. Vegetable food contains much potassium salt, and the sodium salt is required to neutralize its effects. It is important, therefore, to add salt to the diet of an infant who is given vegetable food with its diet, such as barley-water, etc. There is one cereal which contains remarkably little potassium,—namely, rice.

"**Iron.**—Both human milk and cow's milk contain a very small proportion of iron,—namely, 0.003 per cent. of the dried solids; hence, when cow's milk is diluted, the percentage of iron is reduced below that of mother's milk. Deficiency of iron in the food of the hand-fed baby may produce anæmia and debility. To guard against this, iron must be given by the mouth, and, seeing that normally it is taken in the form of organic compounds, it is better to administer it in this form rather than give inorganic preparations. It is doubtful whether iron introduced in the form of inorganic salts can be converted into hæmoglobin by synthesis. Organic ferru-

ginous combinations exist in the yolk of an egg in the form of nucleo-albumins, analysis showing that 0.04 per cent. of the dried solids of the egg-yolk consist of iron.

"In blood and raw meat juice iron is contained in considerable quantity in the form of hæmoglobin. In this combination the iron is more firmly held than in the nucleo-albuminous compound present in the yolk of the egg. Nevertheless, raw meat juice or the gravy of undercooked meat is a valuable addition to the diet of an infant for the prevention and cure of anæmia. After the age of one year potatoes (containing 0.042 per cent. of iron in the dried solids) can be added to the diet. About 0.02 per cent. of iron is present in lean meat, cereals, and leguminosæ, such as wheat and peas.

"**Lime.**—In human milk 0.0243 per cent. of lime is present, in cow's milk 0.151 per cent., and in the yolk of egg 0.38 per cent. Meat, cereals, and leguminosæ contain a much smaller proportion, and it is doubtful whether a child brought up on a diet devoid of milk would obtain the amount of lime requisite for the proper development of its bones. It is uncertain whether this salt can be absorbed except in the form of organic compounds, and it is exceedingly improbable that it is absorbed dissolved in water. There is no evidence that water rich in lime salts has any value whatever in the prevention of rickets.

"Lime-water in saturated solution contains less lime than cow's milk; consequently, the addition of this fluid to milk can exert no influence, except by virtue of its alkalinity. Lime is more soluble in cold than in hot water, so that when lime-water is added to hot milk, some of the salt is precipitated. The lime salts in milk are rendered more insoluble by prolonged heating, as in sterilization.

"**Phosphorus** is of the utmost importance in the formation of bone and probably in the prevention of rickets; so much so that in recent years it has been prescribed for rickets and, according to some authors, with considerable success. Six

times as much phosphorus is present in lean beef, yolk of egg, and cow's milk as is found in mother's milk. Cereals, leguminosæ, and potatoes contain considerably more phosphorus than human milk. Lecithin and nuclein are bodies containing phosphorus, and are found in considerable quantities in nervous tissues and ova. It is not known whether they are absorbed and digested, but the administration of calves' brains and hard roes of fish is certainly harmless. The large amount of phosphorus present in cow's milk indicates that ordinary dilutions will not render the supply of this salt deficient. If it is thought that more is required, it is much simpler to administer the salt in the form of the yolk of egg than in the form of inorganic compounds, and in all probability this is better digested and assimilated."

In order to compare the constituents of an average adult diet and that for an infant of six months, weighing 6.7 kilogrammes, we have taken the average of the figures given in the estimations of von Ranke, Moleschott, Pettenkofer and Voit, and Waller (cited by Cautley), and those for an infant's diet as estimated by Cautley, allowing that a healthy infant aged six months takes a litre of milk daily, and calculating from Leeds's average analysis of human milk.

	Constituents of an average adult diet.	Diet of an infant aged six months. Weight, 6.7 kilogrammes.
	Grammes.	Grammes.
Proteids	121	20
Fat	94	40
Carbohydrates	350	70
Salts	26	2
Water	2629	868

"On comparing the latter with the adult diet it is seen that the infant requires a much more liberal supply of each of the constituents of the ordinary diet in proportion to its

weight, and a much more liberal supply of fat and water compared with its need for proteids. Halliburton estimates the needs of an infant under a year and a half old as from twenty to thirty-six grammes of proteids, thirty to forty-five grammes of fat, and sixty to ninety grammes of carbohydrates. At present it is impossible to give more definite figures, and it must be remembered that the requirements of the individual child may vary to some extent from the average. In regard to proteids, Waller has pointed out that in proportion to body weight the amount required by the infant is greater than that required by the adult, but that in proportion to the body surface the amount is approximately the same. Body surface is therefore a better proportional indication than body weight."

RICHMOND.[121] Milk is of value as a food both to repair tissue waste and as a source of energy. Of its three main constituents:

	Carbon. Per cent.	Hydrogen. Per cent.	Nitrogen. Per cent.	Oxygen. Per cent.
Fat contains....................	75.63	11.87	.....	12.50
Sugar contains..................	42.11	6.43	.....	51.46
Proteids contain	52.66	7.13	15.77	22.77

Fat is richest in carbon and hydrogen, proteids come next, while sugar occupies the lowest place. Neither fat nor sugar can replace the proteids, as these furnish the only source of nitrogen. It is evident that, to build up tissues containing high percentages of carbon and hydrogen, fat is a far more advantageous food than sugar. The value of milk as a food for infants depends largely on the fat present, and it is doubtful whether fat can be replaced by sugar without detriment to anabolic processes.

Strohmer has given the following table of the values for combustion of the constituents of milk:

Fats.....	Butter	furnishes 9231.3	calories per kilogramme
	Other fats	furnish 9500	calories per kilogramme
Sugar	Lactose	furnishes 3950	calories per kilogramme
	Cane-sugar	furnishes 3955	calories per kilogramme
Proteids ..	Casein	furnishes 5858.3	calories per kilogramme
	Albumin	furnishes 5735.2	calories per kilogramme

These values assume that complete combustion takes place. This may be said to be true for fat and sugar; when we consider the proteids, we must remember that the nitrogen is not excreted as such, but as compounds, of which urea may be taken as a type. The heat of combustion of the urea from one gramme of proteids amounts in round figures to fifteen per cent. of the total heat of combustion. It is necessary, therefore, to deduct fifteen per cent. of the heat of combustion of proteids in calculating isodynamic metabolic ratios.

In round figures the following will be the calories per kilogramme developed in combustion of the three constituents in the human body: **fat** 9230, **sugar** 3950, **proteids** 4970.

The author proposes to calculate the ratio between the various constituents as follows:

$$\text{Anabolic ratio} = \text{fat} : \text{sugar} : \text{proteids}; \text{ or, } 2.38 : 1 : 1.26$$

$$\text{Metabolic ratio} = \frac{\text{fat} \times 2.38 + \text{sugar} + \text{proteids} \times 1.26}{\text{proteids}}$$

Instead of the above figures, the round figures 2.5 and 1.25 may be used without appreciable error.

The ratios of mother's milk are: Anabolic ratio = 2.2 : 4.5 : 1
Metabolic ratio = 11.3

The ratios of cow's milk are: Anabolic ratio = 1.15 : 1.4 : 1
Metabolic ratio = 5.54

In calculating these ratios it is assumed that the constituents are all digestible. The marked difference is due to the smaller

amount of proteids in human milk. Experiments have shown that children do not derive the most benefit from milk unless the anabolic ratio approximates 2 : 4 : 1 and the constituents are of such a form that they are as finely divided as possible in the stomach.

The condition of the proteids necessary to produce a fine state of division in the stomach is attained by:

I. Simple dilution with water and the addition of fat and sugar.

II. Removal of casein and the addition of fat and sugar.

III. By acting on milk with a proteolytic enzyme—*i.e.*, peptonizing it—and the addition of fat and sugar.

IV. By adding a preparation of diastase and diluting it and the addition of fat and sugar.

MARFAN.[105] Metabolism experiments have proved conclusively that the healthy adult organism needs for its proper development and growth the five principal food elements, all of which are contained in milk,—namely, fat, proteids, sugar, water, and mineral salts. Nothing can take the place of the proteids, salts, and water. To a certain extent, fat and sugar may be substituted for each other, but any attempt at absolute replacement of the one by the other is sure to lead to digestive disturbances. Water serves as a substratum for nearly all of the chemical changes of the human body. It helps to eliminate the products of metabolism, it keeps the alveolar surfaces moist, thus favoring the diffusion of gases in the lungs, and it plays a considerable rôle in favoring evaporation from the surface of the body. It is thus a factor in the regulation of the animal heat. Forster found that animals fed on foods containing no mineral salts wasted and died in a short period.

The principal physiological characteristic of infancy is that during this period growth is more rapid than at any subsequent period of life, and is the more rapid the younger the child. For example, the child doubles its weight in five months

and triples it in fifteen months; consequently, assimilation predominates largely over disassimilation. To establish the balance of nutrition in the first period of infancy we must note: first, the quantity of food to be taken; second, the increase in weight; third, the number of calories consumed by the infant organism; fourth, the amount of urea, water, and carbon dioxide excreted. Unfortunately, on the last two points our knowledge is still imperfect. For example, a breast-fed infant in good health, weighing on the average five kilogrammes, will take in twenty-four hours about eight hundred grammes of milk, and will gain from twenty-five to thirty grammes a day. The breast-milk which he takes contains in each one thousand grammes fifteen parts of casein, forty parts of fat, and sixty-three parts of sugar. The adult ingests daily for each kilogramme of his body weight one and seven-tenths grammes of albumin, 0.85 gramme of fat, and seven and a half grammes of carbohydrates. The infant ingests per kilogramme twice as much albumin and five times as much fat as the adult (the quantity of milk-sugar being estimated as fat by multiplying by the ratio ten to twenty-four). Assimilation is thus very active in the first period of life. The ratio of the nitrogenous to the non-nitrogenous elements in the diet is as one to five in the adult's food, one to six in woman's milk, and one to three in cow's milk.

According to Lambling (*Le Nord Médical,* January 1, 1898), an infant consumes up to the age of two years one hundred calories per kilogramme per day. This is double the number of calories which would suffice for an adult engaged in moderate work. Rubner thinks that the greater extent of the body surface in infants as compared with their weight causes them to lose much larger amounts of heat during the same periods of time. Lambling has observed that if we compare the number of calories consumed, not to the unit of weight but to the unit of surface, we find that the experiments give the same

results for the infant as for the adult. He has estimated the proportion of heat furnished by the different elements of milk. In one hundred calories furnished to the organism, the following is the ratio of the different elements in the food:

	Adults.	Infants.
Proteids	19	18
Fat	30	53
Carbohydrates	51	29

During the first year the infant consumes one hundred calories per day; from two to five years, eighty to ninety; from five to twelve years, sixty to eighty. The adult consumes proportionately more carbohydrates than the infant, the latter almost double the quantity of fat consumed by the adult. This preponderance of fatty substances is to check albuminous waste in the tissues of the body; part of the fat must be retained to build up the growing structures. After weaning, when the milk is no longer the sole diet, the combustion of fat is replaced more and more by combustion of carbohydrates. The carbohydrates increase until they preponderate as in the adult.

After the first year development is less rapid, and the supply of albumin and fat diminishes, while that of the carbohydrates increases until it is finally almost double that of the fat and albumin together. At the same time metabolism is still very active. From one to two years the infant absorbs per kilogramme twice as much albumin as the adult, three times as much fat, and one and a half times as much carbohydrates.

The alimentary needs of infants at different ages have been calculated by Marfan as follows, on the basis of the researches of Camerer, Forster, Uffelmann, Voit, and Riedel.

Age.	Weight. Kilos.	Per kilogramme. Albumin. Grammes.	Fat. Grammes.	Carbohydrates. Grammes.
Three days	3.00	2.4	2.8	2.9
Six days	3.2	3.7	4.3	4.4
Three weeks	3.5	4.8	5.6	5.7
Seven to ten weeks	4.00	4.5	5.2	5.4
Four months	6.00	3.8	4.5	4.6
One and a half years	9.00	4.4	4.0	8.9
Two and a half years	10.00	3.6	2.7	15.0

With regard to the need of salts for the infant's nutrition, we note that the child fed on milk obtains per kilogramme of body weight a greater proportion of mineral salts than the adult on an ordinary diet. The organism at first needs a considerable quantity of inorganic salts to build up the growing tissues, whereas the adult body can keep itself in equilibrium on a smaller quantity.

During the first year the infant takes on the average four grammes of albumin per kilogramme of body weight,—*i.e.*, twice as much as the adult. Up to five or six months urinalyses show that the infant eliminates less urea per kilogramme than the adult in nutritive equilibrium (see J. Renault, *Traité des Maladies de l'Enfance,* vol. iii. p. 259). Towards fifteen months the infant eliminates more urea than the adult, and the quantity increases up to ten years, to fall subsequently and reach the ratio of adult life; proportionately the infant ingests more nitrogenous material than he eliminates (Carron de la Carrière et Monfet, "The Normal Urine of the Infant after Fifteen Months," *Académie de Médecine,* July 20, 1897). These facts are in accord with the results obtained by weighing. During the first six months growth is more rapid and more nitrogen is retained than during the second six months of the first year.

The researches of Voit and Pettenkofer, Forster, and more

recent ones by Mensi, of Turin, are in accord in showing that the infant organism from birth to ten years eliminates from one and a half to two and a half parts more carbon dioxide than the adult organism. This excessive carbonaceous waste perhaps occurs at the expense of fat, thus serving to economize the albumin needed for growth. Munk, however, attributes it in part to the decomposition of albuminoids. He bases this statement on the fact that in infants carbon dioxide elimination is parallel to that of urea (Munk and Ewald's Treatise on Dietetics).

Phosphorus and Nitrogen Metabolism.

Arthur Keller.[185] Two observations were undertaken to determine the amount of nitrogen excreted in the intestinal secretions and epithelia. In each case the infant was kept for two days on a starvation diet of sugar and water. The results gave 1.0072 and 1.4618 grammes dried fæces respectively, with 0.0716 and 0.0966 gramme nitrogen. While these figures are of course not of general application, they show at least that the amount of nitrogen so excreted is not inconsiderable as compared with the small total content of nitrogen in the fæces.

The absorption of nitrogen may be said to be in general better on a diet of cow's milk than on one of breast-milk. Among breast-fed children the healthiest show the highest figures. Shortening of the pauses between feedings was without influence on the amount of nitrogenous absorption, as was also the addition of sodium phosphate to the diet.

The absolute amount of nitrogen retention depends to a certain degree on the amount of nitrogen in the food, but depends also on the kind of food. When we consider the percentage figures of retention, we find that a greater proportion of the food nitrogen is retained on a diet of mother's milk than on one of cow's milk. Sick children utilize the nitrogen of mother's milk just as well as healthy ones; on the other hand, the state

of the child's health affects quite markedly its power to assimilate the nitrogen of cow's milk. It is also remarkable that when sodium phosphate is added to the food, the utilization of nitrogen is better than in all other cases.

From the tables cited by the author it appears that two influences are of moment for the utilization of nitrogen by the infant organism: the kind of food and the condition of the child's health. Other factors (even the amount of food), unless marked differences exist, possess less importance.

Animal experiments, investigations on the adult, and metabolism experiments on the infant justify the conclusion that the differences in nitrogen metabolism are due, not so much to the different constitution of the albuminous bodies in the two kinds of milk as to the variations in milk-sugar and fat content.

The results and conclusions to be drawn from tables representing the sum of metabolism experiments of different observers on different infants fed on different kinds of food at different times of life and under varying surroundings are to be accepted with reserve. They become of more value when we can control them by experiments carried out on the same child. Keller found that in the case of a child fed first on breast-milk and then on cow's milk, in the latter period less nitrogen was absorbed but more was assimilated than in the former. This observation applies as well to the healthy as to the sick child.

The addition of carbohydrates to cow's milk, in the form of maltose or milk-sugar, diminishes the absorption but at the same time heightens the retention of nitrogen. In correspondence with these results, it is probably true that the higher percentage of milk-sugar in mother's milk shares in bringing about the greater retention of its nitrogen.

Of the nitrogen in the starch, a decidedly smaller part is absorbed (at any rate, in the case of infants) than of the nitrogen in mother's milk.

When malt soup is given, in which one-fourth of the nitrogen comes from the starch, only a smaller proportion of the nitrogen administered will be absorbed, but, notwithstanding, more nitrogen will be assimilated than if we gave the same amount in the form of cow's milk.

Up to the present we have no knowledge of the influence of the fat content on the assimilation of nitrogen.

The addition of salts to the food increases the retention of nitrogen, whereas the addition of hydrochloric acid (Raudnitz) does not affect it.

Phosphorus Metabolism.

Keller finds that the quantity of phosphorus administered in the food is no criterion for the amount of absorption and retention of phosphorus, but that other influences, such as the kind of food and the state of the child's health, are of more moment.

In the case of normal healthy infants these experiments prove quite conclusively that the organic phosphorus combinations of woman's milk, as well as those of cow's milk, become soluble in the digestive fluids. The amount of phosphorus present in the fæces of healthy breast-fed children is very small; besides this, a considerable part of this phosphorus comes from the digestive juices and the intestinal epithelium. The experiments show that the phosphorus in woman's milk can be absorbed almost completely by the healthy child. The same can be said for the phosphorus in cow's milk. The experiments also show that absorption is somewhat more complete in the case of the artificially fed child, but retention of the food phosphorus decidedly less than in the case of the child at the breast. The differences in phosphorus metabolism are more conspicuous in the case of sick children, and here the advantage is again with the nursing child. If we are forced to nourish such a child artificially, favorable conditions for phosphorus retention are furnished by a food which

contains a plentiful amount of phosphates, besides phosphorus in organic combination.

Keller reviews the metabolism work of Bendix, Lange and Berend, and some of his own experiments, and concludes that the results are contradictory and unsatisfactory. There is not enough in them to be made the basis of any definite conclusions. Clinical observation is at present the only reliable guide, and it speaks against excessive administration of proteids.

The metabolism experiments of Rubner and Heubner comprise three cases, all of which were studied with the greatest care. A full account of them can be found in the *Zeitschrift für Biologie.* While such experiments are of great interest, and may in the course of time reach a sufficient number to be of value to the practitioner in giving him a basis on which he may be able to calculate the needs of the organism in food-stuffs, as they are at present carried out, metabolism experiments on the infant do not approximate sufficiently to the normal conditions to be considered final, and we must be very cautious in drawing far-reaching conclusions from the results of a few isolated cases under varying conditions as to the child's age, diet, environment, etc.

Blauberg [193] investigated the mineral salt metabolism in two cases, both healthy, one breast-fed and the other taking pure cow's milk; also the mineral metabolism in an atrophic infant. "Up to a certain degree the conclusion seems justified that too great a dilution of cow's milk has an unfavorable influence on the absorption of the mineral salts of the same. . . . In general, we may safely say that the salts of woman's milk are much better absorbed by the infant than those of cow's milk."

Monti.[90] A milk mixture prepared according to Heubner's method, consisting of equal parts of milk and water and enough milk-sugar to bring the strength of the solution up to six per cent. sugar, will contain the following values of

albumin, fat, and sugar, proportionately to the amount of food taken.

Age.	No. of cc. per meal.	No. of meals.	Total daily amount.	Proteids.	Fat.	Sugar.
			Cc.	Per cent.	Per cent.	Per cent.
One week	30.0	8	240.0	4.08	4.39	14.06
Two weeks	45.0	8	360.0	6.12	6.58	21.09
Three weeks.........	45.0	7	315.0	5.27	5.67	18.16
Four weeks	60.0	7	420.0	7.14	7.68	24.61
Five weeks..........	75.0	7	525.0	8.84	9.36	30.16
Six weeks	90.0	7	630.0	10.71	11.52	36.54
Seven weeks.........	105.0	7	735.0	12.41	13.14	42.34
Eight weeks.........	120.0	7	840.0	14.28	15.12	48.72
Nine weeks	135.0	7	945.0	15.98	16.92	54.52
Ten weeks	150.0	7	1050.0	17.85	18.90	60.90
Eleven weeks........	165.0	6	990.0	16.83	17.80	57.42
Twelve weeks	180.0	6	1080.0	18.30	19.44	62.64
Thirteen weeks	190.0	6	1140.0	19.38	19.52	66.12
Fourteen weeks......	200.0	6	1200.0	20.40	21.60	67.60

Biedert's Cream Mixture.[99]

Age.	No. of mixture.	Weight in grammes of different constituents.				Percentage of different constituents.		
		Cream.	Water.	Sugar of milk.	Milk.	Casein.	Fat.	Sugar.
One week	1	125	375	15	...	1.0	2.5	4.0
Two weeks.	2	125	375	15	60	1.4	2.7	3.8
Three to four weeks...	3	125	375	15	125	1.8	2.7	3.8
Five to six weeks	3	125	375	15	125	1.8	2.7	3.8
Seven to eight weeks..	4	125	375	15	250	2.3	2.9	3.8
Nine to ten weeks.....	5	125	375	15	375	2.6	3.0	3.9
Eleven to twelve weeks	6	...	250	10	500	3.2	2.8	4.0

BIEDERT'S CREAM MIXTURE.

Age.	Average weight.	Total amount of food.	Twenty-four hours food quantity. Proteids.	Fat.	Sugar.
	Grammes.	Grammes.	Per cent.	Per cent.	Per cent.
One week	3000	525– 600	5.25– 6.00	13.13–15.00	21.00–24.00
Two weeks	3375	590– 675	8.26– 9.45	15.93–18.22	22.42–25.65
Three to four weeks	4000	700– 800	12.60–14.40	18.90–21.60	26.60–30.40
Five to six weeks	4350	761– 870	13.70–15.66	20.54–23.49	28.91–33.06
Seven to eight weeks	4700	823– 940	18.93–21.62	23.87–27.26	31.27–35.72
Nine to ten weeks	5025	879–1005	22.85–26.13	25.49–29.15	33.40–38.18
Eleven to twelve weeks	5350	916–1070	29.31–34.24	25.65–29.96	36.34–42.80

Monti.[99] PFEIFFER estimates the values of the different constituents of mother's milk in the subjoined table.

Age.	Total amount.	No. and size of meals.	Proteids.	Fat.	Sugar.
	Cc.		Per cent.	Per cent.	Per cent.
One-half week	104	8 x 13	4.40	2.81	4.69
One week	254	7 x 36	8.74	6.86	11.44
Two weeks	334	7 x 48	7.64	12.13	15.05
Three weeks	449	7 x 68	10.27	12.13	20.23
Four weeks	550	7 x 71	12.58	17.86	24.78
Five to six weeks	749	7 x 107	13.82	22.52	41.47
Seven to eight weeks	864	7 x 123	15.83	26.40	45.03
Nine to ten weeks	926	7 x 132	17.68	20.43	55.28
Eleven to twelve weeks	896	7 x 128	17.10	20.25	53.50
Thirteen to fourteen weeks	966	7 x 138	19.53	39.02	59.12
Fifteen to sixteen weeks	974	7 x 139	19.62	39.23	59.39
Seventeen to eighteen weeks	996	7 x 142	17.38	52.36	.....
Nineteen to twenty weeks	996	7 x 142	17.42	52.28	.....
Twenty-one to twenty-four weeks	1023	6 x 167	15.82	26.88	60.00
Twenty-five to twenty-eight weeks	1051	6 x 174	11.99	34.77	60.40
Twenty-nine to thirty-two weeks	741	6 x 123	12.15	28.69	42.80
Thirty-three to thirty-six weeks	482	6 x 88	7.26	11.62	28.94

CHAPTER XI.

THE FEEDING OF PREMATURE INFANTS.

In the *Archives of Pediatrics,* No. 17, 1900, James D. Voorhees[216] has emphasized some of the most important points in the care of premature infants from his experience at the Sloane Maternity Hospital.

Temperature.—This should be neither too low, which favors excessive heat radiation, nor too high, which increases cell metabolism. From 86° to 92° F. seems to be the correct average.

Fresh Air.—The importance of this can be appreciated when we realize that the tissues of the nose and throat and mouth of the premature infant are extremely sensitive and unable to throw off infectious material conveyed by the dust.

The infant should lie on a very soft pillow. Preliminary bathing should be avoided. If wrapped in cotton, this should not be placed directly next to the skin, but a light shirt and diaper should be first employed. The infant should not be disturbed to change the latter oftener than absolutely necessary.

Feeding.—As a routine practice, within six hours after birth Voorhees begins by administering from one-half to one drachm of a five to six per cent. lactose solution every hour. In from twenty-four to thirty-six hours he adds equal parts of breast-milk, preferably obtained from a wet-nurse who is from seven to eight days post-partum. The amount at each feeding is increased one drachm at a time until on the seventh day the baby is taking from six to eight drachms every hour.

If the stools are normal, the proportion of milk can be increased and the sugar solution decreased. By adding a little

lime-water, pure breast-milk can often be used at two weeks of age. The infant will usually nurse through a small nipple. In some cases we may have to make use of a medicine-dropper, and occasionally, when the infant is very weak or unable to swallow, gavage is necessary. In the latter case, however, they seldom do well, as regurgitation is almost sure to occur. In this way the nasopharynx is filled, and on the next inspiration some of the fluid is drawn into the larynx and even into the bronchi.

When the diet consists of pure breast-milk, the intervals should be gradually increased to two hours, so that by the time full term is reached the amount and interval will correspond to those of the normal infant.

The results with diluted cow's milk are not nearly so satisfactory as with the above plan.

Weight.—Premature infants lose considerably more in proportion to their birth weight than babies at term, and regain their original weight more slowly. Indeed, if this has been accomplished by the end of the second or third week they have done remarkably well.

In regard to the use of the incubator, the general rule at the Sloane Maternity Hospital is to put the infant in cotton and surround it with hot-water bottles when its weight is near five pounds. If it does not thrive, or if the temperature falls, the incubator must be used. Those weighing four and a half pounds or less are put at once into the "couveuse."

According to the statistics of Tarnier, Charles, and the Sloane Maternity Hospital:

At six months of age	from 10–16 per cent. are saved
At six and a half months of age	from 20–30 per cent. are saved
At seven months of age	from 40–49 per cent. are saved
At seven and a half months of age	from 75–77 per cent. are saved
At eight months of age	from 70–88 per cent. are saved

VANDERPOEL ADRIANCE.[184] The importance of proper feeding in cases of prematurity cannot be overestimated. In the

first place, the gastro-intestinal tract is so poorly developed that fats and proteids are feebly digested. If modified milk is administered, it must be weak, not containing more than one per cent. of fat and 0.50 per cent. of proteids, until the alimentary tract is educated to its task. Modified milk is warmly recommended by Rotch, of Boston, but our experience indicates that it should not be used when proper breast-milk is available.

Mother's milk is the ideal food, and every premature infant should have it if its variations and management are properly understood. The excess of proteids in colostrum milk is due to the sudden assumption of the mammary function. The breasts are unexpectedly engorged with an increased blood-supply and the mammary cells forced to activity. It is no marvel that during this strain the secreting cells permit of a serous transudation and that an excess of albumin is found in the secretion.

The milk offered by the breasts during the first days after a premature labor is colostrum milk, and has its characteristics, but to an exaggerated degree. The marked increase in the amount of proteids is especially noticeable. The excess continues longer, and it is not easily dispelled. It has even been found persisting as high as two per cent. in the second month.

Analyses of Premature Milk at Successive Times.

	Four days. Per cent.	Seventeen days. Per cent.	One month and ten days. Per cent.
Fat	3.39	3.32	3.33
Carbohydrates	5.02	4.43	6.64
Proteids	4.90	3.88	1.71
Salts	0.31	0.26	0.10
Total solids	13.66	11.91	11.79
Water	86.32	88.08	88.20

These analyses demonstrate an excessively high proteid percentage, accompanied by a correspondingly high percentage of

salts. The amount of carbohydrates is lower than in any other series of milk analyzed. The management of this condition is difficult, since the milk of prematurity persistently maintains this high percentage of proteids. It may be reduced by giving large quantities of water to the mother or by pumping the milk and diluting it with sugar of milk solution. Even if our efforts are successful, however, the milk presents different characteristics from that later in lactation and cannot be administered with safety.

In cases of prematurity, then, a wet-nurse should be secured. Her infant must be healthy, full term, and two weeks of age (better, a month), in order that the characters of the colostrum period may be lost, and nothing will better determine the quality of her milk than its chemical examination. Meanwhile the secretion of the mother should be maintained by pumping and massage, so that it can be resorted to at the proper time.

CAUTLEY.[38] Hecker and Lusk give the following table, showing the weight of premature infants and the normal daily increase.

At twenty-four weeks they should weigh 690 grammes; at twenty-eight weeks, 1170 grammes; at thirty-two weeks, 1560 grammes; at thirty-six weeks, 1920 grammes; at thirty-eight weeks, 2310 grammes. During this time they should gain daily from 0.75 to one per cent. of their weight.

Potel, from the investigation of three hundred and fifty cases, gives the following estimates:

Age.	Weight.	Average daily gain in weight.
	Grammes.	Grammes.
Six and a half months....................	1400	9.4
Seven months	1700	11.5
Seven and a half months	1900	13.8
Eight months	2150	22.8

Of these three hundred and fifty cases nearly fifty per cent. survived. The gastric capacity may be roughly estimated at

one per cent. of the body weight. In modifying milk to suit these cases we use the same constituents, simply reducing the percentage of solids.

Rotch gives the following formulæ: Formula I. At from twenty-eight to thirty-six weeks, proteids 0.5 per cent., fat one per cent., sugar three per cent. If the infant is not satisfied, or if the child is unusually large, or when it is thirty weeks old, we may give Formula II.: proteids 0.5 per cent., fat 1.5 per cent., sugar four per cent. If the infant is over thirty-two weeks old, give Formula III.: proteids 0.75 per cent., fat 1.5 per cent., sugar five per cent.

Give twenty-four meals a day: of Formula I. four cubic centimetres each, heated to 75° C.; of Formula II. eight cubic centimetres each, heated to 75° C.; of Formula III. twelve cubic centimetres each, heated to 75° C. If the infant is over thirty-six weeks old, give Formula IV.: proteids one per cent., fat two per cent., sugar 5.5 per cent. Give twenty-four meals a day, of sixteen cubic centimetres each, heated to 75° C.

If the infant cannot digest these mixtures, try condensed milk or a mixture of egg albumin, water, cream, and sugar. Raw meat juice must also be given. It is better to feed frequently and in small quantities than to risk causing dilatation of the stomach and gastro-enteric disorders by giving larger quantities less frequently.

If the child is thriving, we can gradually increase the intervals until at term it takes normal amounts at normal intervals. If the infant is too weak to nurse, special apparatus has to be employed which will force food into its mouth, or gavage must be resorted to.

Ashby and Wright.[2] It is probably best to draw off the mother's milk, dilute it, and feed the premature infant through a pipette. Failing in this, sterilized whey may be used, diluted with water if necessary. Give from two to four drachms every hour.

CHAPTER XII.

PRINCIPLES OF INFANT FEEDING.

WHEN we survey the various methods which have been advocated in different parts of the world for the artificial feeding of infants, we encounter wide differences of opinion.

In England, France, Germany, and Austria the prevailing tendency is to feed the infant on milk mixtures containing high proteid percentages. Milk diluted one-third or equally with water, and sweetened, is considered the proper food for a healthy babe during the first months of life; this diet is continued until at the age of eight or nine months whole milk is given. Although there is a rather low fat percentage in such mixtures, those who advocate this method of feeding do not consider that it is necessary to remedy the deficit in fat by the addition of cream; some of them advise the addition of an excess of sugar to take the place of the fat. Sterilization of the milk is considered practically indispensable by most French and German pediatrists.

Attempts have been made by Heubner and others to base the food requirements of the infant on the number of calories daily consumed, taking as a basis the number of heat units furnished by definite quantities of mother's milk (the composition of the latter being assumed to be fairly constant). But when we consider how markedly the needs of different infants vary, depending on their rate of growth, strength, digestive capacity, etc., it seems certainly more advisable to follow broad practical lines in the regulation of their diet than to estimate their food requirements according to strictly scientific principles.

The majority of leading American writers and teachers emphasize the necessity for greater dilution of cow's milk to render it easy of assimilation by the young infant. They advise to begin the administration of cow's milk by diluting it three or four times with water, gradually increasing the strength of the milk mixture until the end of the first year or later, when whole milk can usually be given without harm. To compensate for the low percentage of fat which results from high dilution of milk, the addition of small quantities of cream to the milk mixture is advised, while the percentage of sugar is increased by the addition of milk-sugar until it equals six or seven per cent., the proportion present in mother's milk.

When the process of sterilization was introduced, American physicians were among the first to recognize its importance and the necessity for its employment under certain conditions and at certain times of the year, to render milk fit for the infant's use. They were equally prompt to note the advantages of pasteurization; the latter method of heating milk soon came into general use in America, while it is only of late years that much notice of it has been taken by Continental authorities.

Unquestionably the greatest step in advance in recent years towards the successful hand feeding of infants has been the discovery that it is possible to produce practically pure sterile milk, and thus dispense with sterilization altogether in preparing the child's food. To Henry L. Coit, of Newark, belongs the credit of having demonstrated the fact to the American profession and to the public at large that pure so-called "certified milk" could be obtained by instituting proper hygienic precautions regulating the production and care of the milk. "Certified milk" can now be obtained in quite a number of our large cities. Its price is necessarily higher than that of ordinary milk, but it seems probable that, when the public becomes sufficiently alive to the importance of obtaining clean

milk, competition will reduce its cost and bring it within the reach of all. Sterilization and pasteurization will then become of minor importance.

As Baginsky has well said, the chief requisite for success in the management of the infant's diet is the ability to make a thorough study of the needs of the individual case and to treat the child accordingly. Since no two children have identical food requirements, the physician who can correctly determine the qualitative composition of the food—that is, the relative proportion of the different ingredients suited to the particular case—will be more successful than he who prescribes a definite quantity of a food which, theoretically or on scientific grounds, the infant should be able to digest.

For the convenience of the reader it has seemed advisable to classify the various methods advocated for the feeding of healthy infants before discussing in detail the principles involved.

I. Whole Milk.—Some pediatrists, most of them French, contend that whole cow's milk, provided it has been sterilized, can safely be administered even to the youngest infant. This view has not found general favor in this country. It is contrary to the great mass of clinical evidence, which has taught us that the majority of healthy infants cannot properly digest pure cow's milk until near the end of the first year. Undoubtedly there are numerous exceptions to this rule. Czerny and Schlesinger have called attention to the fact that in some cases of malnutrition from improper feeding nothing is so satisfactory as the administration of small amounts of whole milk at long intervals (from three to five hours). No doubt many of these cases had previously been fed on excessive amounts of highly diluted milk mixtures which did not contain enough nourishment to meet the demands of the organism. When excessive quantities of water are given in this way for long periods of time, we fail to supply the necessary physiological stimulus to the gastric secretions, we interfere with digestion

by dilution of the gastro-intestinal juices, and we run serious risk of causing dilatation of the walls of the already enfeebled stomach. We must therefore not lose sight of the fact that in a certain class of cases it may be expedient to resort to a diet of whole milk long before the child, from the theoretical stand-point, could be expected to digest it.

II. Moderate Dilutions (*i.e.*, High Proteids).—Many pediatrists advise plain dilutions of milk with water or barley-water with sugar added. Heubner, Marfan, and Koplik are prominent advocates of this method of feeding, which is based on the conviction that the healthy infant can digest, even at an early age, a mixture containing two parts of milk and one of the diluent (the so-called Heubner-Hoffmann Mixture). Average milk diluted one-third will contain about two and a half per cent. proteids and from two to two and a half per cent. fat. Enough lactose should be added to make the proportion of sugar seven per cent. Undoubtedly many infants will thrive on this mixture, which has at least the advantage of simplicity of preparation to recommend it. When we consider, though, the frequency with which cases of indigestion and malnutrition are encountered among infants who have been fed during the first months of life on milk so slightly diluted, we must recognize that a very large proportion, even of healthy infants, cannot digest and assimilate the Heubner-Hoffmann Mixture at this period. The high proteid content of this mixture constitutes the chief difficulty for the digestion of the young infant; at a later period of life (six months and over) the low fat content will be an objection.

III. High Dilutions (*i.e.*, Low Proteids).—Biedert, John Forsyth Meigs, and Jacobi were the first to uphold the doctrine that cow's milk should be diluted for the young infant three or four times with water until the proportion of proteids is reduced to about one per cent. (milk one part, water three parts, give proteids one per cent., fat from three-quarters to one per cent.). They arrived at this conclusion as the result

of their clinical observation before the amount of casein in mother's milk had been accurately determined. (The idea of adding cream to the milk mixtures to supply the deficit of fat caused by dilution seems to have originated with Biedert abroad and with the elder Meigs in this country.) Undoubtedly the administration of high dilutions of milk with cream and sugar added is one of the most widely applicable and most serviceable methods of infant feeding.

IV. Top-Milk Mixtures.—Instead of adding cream to dilutions of milk and water, dilutions of top milk may be employed. It is convenient to denominate as "top milk" the upper layers of milk which has stood for a sufficient length of time (from twelve to twenty-four hours) to allow the gravity cream to rise to the surface.

V. Whey Mixtures.—Monti, of Vienna, is the principal advocate of the use of whey and milk mixtures for healthy infants. Whey may be added to either milk or cream. The advantages of such mixtures are obvious. We can give almost any desired proportion of casein and fat together with the easily digested whey-proteids. Such mixtures are especially adapted for difficult cases in which the digestion of casein is at fault.

VI. Laboratory Milk.—The introduction of the Milk-Laboratory is the work of T. M. Rotch, of Boston, and represents one of the latest advances in the scientific feeding of infants. The great advantage of Laboratory Milk is that we can be sure of the exact composition of the milk food we are giving. We are able to call in our prescriptions for any desired percentage of the different ingredients and can practically eliminate the danger of the milk becoming contaminated before it reaches the consumer.

One objection has been raised against Laboratory Milk prepared with centrifugal cream,—namely, that the natural condition of the elements of the milk is replaced by an artificial combination of these elements; to accomplish this, the milk

is first separated into a solution of proteids (fat-free) and a solution of cream with low proteids, and then recombined. It is an open question whether the physical and chemical characteristics of the milk (the state of the emulsion of the fat-molecules) are not affected by such manipulations so as to render Laboratory Milk more difficult of absorption and assimilation; in other words, we may question whether the milk has not lost, to some extent at least, its vital characteristics. However this may be, the clinical experience with Laboratory Milk of such well-known pediatrists as Jacobi, Starr, and Koplik has been of such a character as to modify the enthusiasm with which this product was first received. On the other hand, Rotch, Holt, Northrup, and many other competent observers are firm believers in the value of Laboratory Milk. The advocates of this method of feeding can find no proof that the emulsion of the fat is in any way affected by the manipulations in the laboratory. We may perhaps best summarize the situation by stating that Laboratory Milk represents a great advance in modern methods of feeding; it is successful in a large proportion of cases when sufficient experience with its proper application has been gained, but it fails in a certain percentage of cases, even in the best hands. Intelligent home modification of milk still remains our chief resource for the feeding of the great majority of infants, since the expense of the laboratory product puts it out of the reach of all but the well-to-do.

One great advantage of the Milk-Laboratory to the community consists in the fact that it furnishes a pure product of known and definite composition. The standard required for Walker-Gordon milk has already served to excite competition among milk dealers and has increased the supply of milk suitable for the purposes of infant feeding. It has also drawn the attention of the public to the necessity for hygienic regulations controlling the purity of such a universally used food as cow's milk.

Under these six headings we have outlined the principal methods in use at the present day for the feeding of healthy infants. Before deciding what plan we should adopt, we must consider what are the food requirements of the individual infant. This we know to be a variable factor depending on the child's age, weight, rate of growth, degree of muscular development, etc. The previous methods of feeding, and the existence of gastro-intestinal catarrh due to improper selection of the child's food, must also be taken into account when we are estimating the infant's actual powers of digestion.

The regulation of the quantity of food to be given at each feeding and the interval between meals is of equal importance with the decision what the child's food shall be. Those who advocate high proteid mixtures believe that the infant digests casein slowly; they therefore prolong the pauses between feedings to three hours or even longer for dyspeptic as well as healthy infants. They believe that small quantities of milk mixtures containing high proteid percentages will be better tolerated than weaker mixtures containing an excess of water. On the other hand, those who believe in greater dilution of the milk consider that it is better to feed at shorter intervals (from two to three hours), taking care not to give the child an amount of fluid in excess of the gastric capacity. Sometimes a failure to gain in weight, in the absence of dyspeptic symptoms, shows the necessity of increasing the total quantity of food without altering the strength of the mixture, in order to re-establish the nutritive equilibrium.

The tables of Holt, Rotch, and Pfaundler (Chapter IV.) should be consulted in order to determine the average capacity of the stomach at different periods of infancy.

The child's age is a good general guide on which to base the amount of food required, but it must not be forgotten that there are many children in whom increase in gastric capacity does not run parallel with the gain in age or the increase in weight; in these cases the gain in body length may serve as a

guide (Pfaundler). Careful clinical observation will, however, rarely fail to determine correctly what quantity of food the infant is capable of digesting successfully.

We must next decide what proportions of the different elements of milk are best adapted to the infant's needs. Perhaps the most important question is, How much proteid or nitrogenous food shall we give?

Proteids: Casein and Albumin.

In spite of the teachings of Heubner, Czerny, and others, and the metabolism experiments of Keller, Heubner, and Bendix, which seem to prove the contrary, the statement must be reiterated that the chief obstacle to success in the hand feeding of infants consists in the difficulty in digestion of the casein in cow's milk. The differences in the behavior of mother's milk casein and cow's milk casein, when introduced into the infant's digestive tract, are well known. The former coagulates in small, soft, homogeneous masses which are readily penetrated by the gastro-intestinal juices and are easily redissolved, while the latter forms large, tough, irregular curds which are difficult of solution and are often passed only partially digested through the intestinal tract. Moreover, we must emphasize the fact that mother's milk and cow's milk are two distinct fluids adapted physiologically to widely different purposes, and that the digestive powers of the babe in arms and those of the calf are very unequal factors.

Since no amount of modification, however scientific, can render cow's milk exactly like mother's milk, it is well to dismiss from our minds the idea that *all* we have to do is "to imitate maternal conditions." This is especially true of the early months of life, when great and irreparable damage to the infant's digestion frequently follows and is the direct result of faulty methods of feeding. Suppose an infant three or four weeks old were taken from the breast and given a milk mixture imitating in composition the natural secretion

at this period of lactation. We would then constitute the child's food as follows: proteids from one and three-quarters to two per cent., fat from three to four per cent., sugar six per cent., and salts 0.2 per cent. Certainly there are not many infants, even if we include those with unusually well-developed powers of digestion, who are capable of digesting a mixture of this composition without harm at this period of life. Therefore, when we have to feed infants on cow's milk, *the essential to success is that the child's gastro-intestinal tract be gradually accustomed to the digestion of cow's milk casein.* If the first steps in this process of education are correctly carried out, the infant will soon acquire the power to digest relatively large amounts of cow's milk proteids. Should the first steps be wrong, however, incalculable injury will result which may take months or even years to remedy.

As a general rule, when we first administer cow's milk to the infant, it is well to reduce the proteids to rather low proportions (one per cent. or less). If this is necessary when we are weaning the breast-fed child who is nine months or one year old, it becomes imperative when we have to feed an infant under three months of age for whom the maternal nourishment has failed. In such a case our choice will usually lie between two methods. Either we may reduce the proportion of casein in cow's milk by dilution until a percentage is reached which the child is able to digest (this will vary from one per cent. for healthy infants during the first month to as low as 0.50 per cent. or even 0.25 per cent. for the new-born and those who are delicate or have weak digestions), or as an alternative we may use peptonized milk, modified by the addition of cream and diluents. The advantage of this method of feeding is that it enables us to give the infant a larger amount of proteids than he would be able to digest in the raw state. For a new-born infant the proportions of our peptonized milk mixture should be about one per cent. proteids, from two to two and a half per cent. fat, and six per

cent. sugar. If this is well tolerated, the strength of the mixture may be increased to one and a half per cent. proteids, three per cent. fat, and six per cent. sugar at the end of the fifth or sixth week. If it is desirable to continue this mode of feeding during the third and fourth months, the proportions may be increased to proteids two per cent., fat three and a half per cent., and sugar seven per cent.

It must be understood that peptonization is only a temporary expedient, and that it is inadvisable, except for difficult cases, to continue the process over a longer period than two or three months. By gradually reducing the time of peptonization, there will seldom be any difficulty in replacing this food with a milk mixture containing the same proportions. It is well known that the most critical period in the life of the artificially fed infant is the first three months. *During this time, therefore, the proportion of casein in the infant's diet* (*unless it is peptonized*) *should rarely exceed one per cent.* By beginning with low proportions of casein and gradually increasing the proteid strength of the mixture we can accustom the child to its digestion, so that the average healthy infant in fair hygienic surroundings will thrive at the age of *six months* on a mixture containing from *one and a half to two per cent. proteids,* and at the age of from twelve to sixteen months will be able to take whole milk.

Delicate infants with weak digestion, cases of malnutrition, and the like generally require dilute mixtures with low proteids. For them we must increase the proteid percentages slowly and cautiously, since they cannot digest the proportions of proteids suitable for healthy infants until a much later period of life.

There are some infants who seem unable to digest more than minimal amounts of cow's milk proteids and fats, so that any attempt to increase the strength of the milk mixture in order to maintain the proper nutritional equilibrium is followed by gastro-intestinal disturbances. In these cases we must

resort to peptonized milk, whey-cream mixtures, egg albumin, beef juice, meat broths, dextrinized attenuants, etc.; or we may use such preparations as Steffen's veal broth, Gregor's malt soup, or somatose milk. Pure buttermilk is said to be successful in a certain proportion of cases (see page 113). When the infant's digestion has regained to some degree its normal powers, we should again try to feed the child on plain mixtures of milk and cream. Exceptionally we meet cases in which even such mixtures are not tolerated before the end of dentition; the selection of the proper food then becomes a problem of great difficulty.

Fat.

The fat of cow's milk, like the casein, is less easily assimilated than the same ingredient in mother's milk. It stands next to casein in difficulty of digestion. We know (see Chapter IV.) that there is always an excess of fat excreted in the fæces, and that this condition may become pathologically exaggerated until actual enteritis results (Biedert's fat diarrhœa). In deciding, then, what percentage of fat must be given in the infant's food, we must bear in mind that moderate rather than high percentages usually give the best results. Two per cent. of fat may safely be administered to the newborn child, and the percentage may be soon increased to three, provided the infant is healthy and has a vigorous digestion. During the first four or five months of the child's life it is rarely necessary to reduce the percentage of fat below two, and rarely advisable to exceed the limit of three and a half. In some cases it is permissible to increase the proportion of fat to four per cent. during the second half of the first year; for the great majority of infants, however, the limit of three and a half per cent. of fat had best not be exceeded until the child is put on a diet of whole milk.

It is evident, then, in considering the question, How much fat does the infant require? that we are unable to imitate very closely maternal conditions. While the healthy breast-

fed infant can digest and assimilate large amounts of fat (four per cent. and over), even in the first months of life, the bottle-fed baby can rarely take with advantage more than three per cent. of fat at the same period; sometimes even this amount will not be tolerated.

The success with which some babies are raised on a diet of condensed milk or cow's milk simply diluted with water would seem to indicate that certain children thrive, for a time at least, on low fat percentages. Such cases must be the exceptions, however. They often show subsequently signs of improper nutrition (rickets, anæmia, scurvy, excessive fat deposits, etc.). The rapidly growing organism requires a plentiful supply of fuel, which is furnished it in the hydrocarbons and carbohydrates, while the larger part of the nitrogen serves to build up the rapidly growing muscular system. The starches and fats thus diminish the consumption of nitrogen, and may be considered "nitrogen-savers."

The proportion of the nitrogenous to the non-nitrogenous elements in the infant's diet is a matter of great importance. We must not overlook the fact that the average ratio of these elements in the child's natural food (the breast-milk) is about one nitrogenous to seven and a half non-nitrogenous, whereas in cow's milk the average ratio is about one of the former to two and a half of the latter. In a rough way we may estimate that mother's milk contains twice as much fat as proteids and four times as much sugar. On the other hand, cow's milk, when undiluted, contains almost equal proportions of proteids, fat, and sugar; hence the non-nitrogenous elements constitute not much more than twice the nitrogenous, whereas the "nitrogen-savers" of mother's milk exceed the nitrogen-carrying elements more than seven times. The importance, therefore, of a sufficient supply of fat and sugar for the proper growth of the infant can scarcely be overestimated, since that child will thrive best in whose diet the different food elements properly balance one another. Yet

some authorities on children's diseases still recommend plain dilutions of milk with water which neither satisfy the normal requirements of the infant nor allow full play for its metabolic activities.

We may supply the deficiency in fat caused by dilution in either of two ways: by adding fat directly to the milk mixture in the shape of cream or by making use of top milk which contains a fairly large proportion of gravity cream. In the former case we may follow the method in vogue at the Walker-Gordon Milk-Laboratory, where a small amount of centrifugal cream with high fat (and low proteid, sugar, and salt) percentage is added to separated milk (a solution containing proteids, sugar, and salts, but almost no fat); in other words, we mix two solutions, one with high fat and the other with high proteid content, to obtain the percentages we desire; or we can add cream to whole milk, according to some of the formulæ devised by Westcott, Baner, and others (see Chapter XIII.). If we use top milk, we dilute our proteids and fat at the same time, and the calculation is simplified. The great advantages to be gained from the use of top milk are that the natural emulsion of the fat is in no way disturbed, and that the same relative proportions of proteids to fat obtain which are found in mother's milk,—namely, the amount of fat is twice or three times that of the proteids. The objections which may be made to top milk are twofold. First, it may be urged that there is great liability to error in calculating the fat percentage, unless frequent analyses of the milk are made. Secondly, since the milk must stand for a long time (from twelve to twenty-four hours) before the gravity cream will come to the surface, it will almost certainly be infected by the bacteria which rise with the cream. It will be shown in the next chapter that the first objection may prove a serious one. The danger of bacterial contamination will be slight if we can obtain "certified" or equally pure milk, bottled at the dairy and kept below

45° F. till it is used; if desired, this milk may be pasteurized immediately after milking.

We must not forget that ordinary commercial cream is more often than not unfit for the infant's use. Centrifugal cream has the advantage of being fresh; it is still open to question, however, whether the mechanical disturbance caused by separation does not affect its digestibility and absorbability.

Sugar.

Sugar is the only carbohydrate normally present in milk. It seems probable that the lactose in cow's milk is not identical with that of mother's milk. This difference of composition is of less consequence for the infant than the differences in the fat and the proteids, since milk-sugar causes serious digestive disturbances much less frequently than either of the other constituents of milk. The majority of pediatrists use lactose, the natural sugar of milk, for the purposes of infant feeding, although some competent observers consider cane-sugar preferable. Maltose is recommended by Keller. During the first weeks of life and for sick or delicate infants the proportion of sugar in the milk mixture should not exceed five per cent. Later this can be increased to six or seven per cent. If there are digestive disturbances, the quantity of sugar must be reduced. When the administration of starchy foods is begun, the proportion of sugar need not exceed that found in whole milk,—about 4.5 per cent. It is important that a pure preparation of milk-sugar be used. Holt advises that it be dissolved in boiling water; it must be prepared freshly each day and filtered through absorbent cotton before it is used, to remove accidental impurities.

Salts.

The percentage of salts present in milk mixtures is usually disregarded, since it is considered that their proportion will not be reduced below that of mother's milk by any ordinary

degree of dilution. It is true that the salts of cow's milk exceed those in mother's milk over three times; so that we may dilute cow's milk to this extent and still have about the same proportion of mineral matters as is present in mother's milk. It would seem, however, from Blauberg's careful study of the fæces in connection with Heubner's metabolism experiments, that the salts of cow's milk (undiluted) are not so well assimilated as those of mother's milk, and that it is doubtful whether dilution of the milk compensates for this difference. Moreover, the amount of sodium chloride in cow's milk is already less than that in mother's milk; hence the importance of adding salt to the infant's food, a point to which Jacobi has long since drawn our attention. It seems probable, too, that the breast-fed infant can assimilate phosphorus more completely than the artificially nourished child, since much of this mineral is present in the breast-milk in organic combinations which seem to be more readily absorbed.

The amount of calcium salts in cow's milk is half again as great as that in mother's milk; but when we dilute cow's milk two or three times, the proportion of lime salts falls decidedly below that present in mother's milk. The same holds true of the phosphates, provided any considerable degree of dilution is practised. In the present state of our knowledge, it is impossible to decide absolutely as to the importance of these salts in the infant's metabolism.

Starch.

Most authorities favor the use of decoctions of cereals as diluents, believing that this facilitates the digestion of casein, besides adding slightly to the nutritive value of the milk mixture. Undoubtedly there are some infants who cannot digest any form of starch until dentition is well advanced, but it is equally true that a larger number are decidedly benefited by this addition to their food. In some cases starch proves to be of distinct advantage as a tissue-saver, since it checks

albuminous waste. Again, the use of a starchy decoction before the administration of the milk mixture often seems materially to aid in the digestion of the proteids, particularly when there is a tendency to gastric intolerance of proteids due to rapid curdling (Holt). When the administration of carbohydrate food is indicated before the period of dentition, the starch may be dextrinized, since it is more easily digested in this form and possesses greater nutritive value. In some of the best infant foods on the market practically all of the starch is dextrinized; they can, therefore, be used as adjuvants to milk when the administration of starch is indicated.

Whey.

Monti deserves credit for calling attention to the importance of whey as a diluent for cow's milk. The whey-proteids are easily digested; they resemble the soluble albumins of mother's milk in their physical and chemical properties, and the replacing of a portion of the casein of cow's milk by soluble albumin in this form has proved of decided value for the infant's nutrition.

The amount of soluble albumin in cow's milk is estimated to be about 0.50 per cent., while the total whey-proteids average from 0.80 to one per cent. Thus it appears that these whey-proteids comprise not only the soluble albumin in cow's milk, but also a portion of the casein which has been converted into a soluble form by the action of rennin. By the use of whey instead of water as a diluent we can materially increase the proportion of whey-proteids in our milk mixture and avoid the administration of large amounts of casein. Whey may be mixed with milk, top milk, or cream in any desired percentage, or it may be given alone to premature or weak infants; it is particularly valuable as a means of beginning the administration of milk after an acute attack of indigestion. Whey-cream mixtures yield a much finer coagulum than plain milk and cream mixtures with the same proteid content.

Peptonized Milk.

The indications for the use of peptonized milk have already been given. Milk and cream may be mixed in any desired proportion and the process of peptonization can be carried out for from ten minutes to half an hour or longer. It requires about two hours to completely peptonize milk. The use of predigested milk offers disadvantages in that this food does not furnish the necessary physiological stimulus to the infant's stomach, since it is offered already prepared for intestinal digestion and absorption. Where the milk is only partially peptonized, this objection has less weight. It is well to begin with half an hour's peptonization, gradually reducing the time as the infant's digestive powers regain their normal condition.

Egg Albumin.

Ever since the investigations of Lehmann showed the presence of soluble albumin in mother's milk various methods have been devised to provide a substitute for this easily digestible constituent. Hesse was the first to use egg albumin in his infant food. Now there are various preparations on the market which base their claims to be perfect substitutes for the maternal nourishment on the presence of a certain amount of white of egg. Apart from the question of its digestibility, there seems to be some reasonable doubt whether egg albumin is sufficiently well assimilated to aid very materially the infant's nutrition. At the same time it serves a useful purpose at certain critical periods when the administration of milk in any form is contraindicated. Egg albumin may be given either mixed with water and a little salt or added to various decoctions of starch, meat broths, etc. It is probably inferior to whey in nutritive value.

Beef Juice, Broths, Peptonoids.

Usually these preparations are not added to the infant's diet till the time of weaning or at the end of the first year.

Before this time they may be used during attacks of milk infection, or as accessories to the diet in cases of anæmia, rickets, etc. When the child is unable to digest large amounts of casein, beef juice and broths often prove of great service, since they furnish proteids and salts in readily assimilable form. When diarrhœa exists, mutton broth is preferable to veal or beef broth. The concentrated foods, such as the liquid peptonoids, panopepton, etc., prove of distinct value during gastro-intestinal affections when all milk must be withheld. The small proportions of alcohol they contain especially commend them in those cases where there is marked constitutional depression.

Lime-Water.

The addition of lime-water to cow's milk is generally considered to be the best means of reducing the acidity of the latter. The greater acidity of cow's milk as compared with mother's milk is a point on which much stress has been laid; but this is purely a relative matter, depending on the care and cleanliness observed in the handling of the milk, the number of lactic and other acid-producing bacteria present, and the temperature at which the milk is kept before it reaches the consumer. The amount of lime-water required is variously estimated at from one-twentieth to one-fourth the total quantity of the mixture. For "certified milk" the proportion of one-twentieth will be sufficient, but if any marked degree of acidity is present in the milk, it will be necessary to use larger quantities to attain our purpose.

The use of lime-water as a routine practice seems hardly necessary when the infant's digestion is healthy and the milk supplied in a fresh condition. If the milk mixture is sterilized by heat, lime-water must be added subsequently.

Weight.

To ascertain whether or not the child is thriving the practitioner has no single guide of greater value than the informa-

tion obtained by weighing the infant at weekly intervals. Roughly stated, a healthy child should gain from six to seven ounces a week during the first three months, from four to five ounces a week between the fifth and the seventh months, and from two to three ounces a week between the ninth and the twelfth months. During the second year the rate of gain is approximately from one and a half to two ounces a week.

Of course many children gain irregularly in weight, more especially those who are artificially fed on an ill-assorted variety of food. Again, a child may increase rapidly in weight during one week and make little or no gain the next, and still be in good health. However, we may assume that a fairly constant rate of gain is the normal condition of the infant, any marked departure from which indicates disturbance of nutrition, which, again, is due in the great majority of instances to faulty methods of feeding.

Sterilization and Pasteurization.

A question which will infallibly present itself to the practitioner concerning the preparation of the milk mixture is whether it will be necessary to apply heat to guard against the danger of milk infection. Our decision will be based on the condition of the milk when it reaches the consumer. If we are able to obtain pure milk which can be kept cold before and after it reaches the consumer, and if there is little or no danger of its contamination during the process of preparing the infant's food, it will be unnecessary to employ any method of pasteurization or sterilization, at least during the cool months of the year.

When contamination of the milk has already occurred or is likely to occur during the handling it undergoes on the part of the mother or nurse, it becomes almost indispensable to apply heat in some form or other. The degree of heat necessary to destroy the bacteria present in milk has been the subject of much debate. It is almost impossible to reconcile the

many conflicting statements. We must remember, though, that many of these assertions are not based on the results of original research, but are copied from the work of other investigators, often without corroboration of the methods employed. More extended observation and more perfect knowledge of the life-conditions of the different species of bacteria will be required before we can advocate definite degrees of temperature for their destruction with absolute certainty of success. We must also not lose sight of the importance of the unorganized ferments present in milk; since they play a rôle in the digestive process, their destruction by heat cannot be regarded as immaterial for the child's welfare. In this field we have probably still much to learn.

From the evidence at hand, without being able to add the results of original investigations, we have attempted to specify what we may expect to accomplish by the application of heat, allowing a certain range in the degree of heat to be used to compensate for possible errors. Heating from 60° to 68° C. (140° to 155° F.) for thirty minutes (the milk being kept in closed bottles to prevent the formation of a pellicle on the surface) will destroy or render innocuous the tubercle bacilli and the common pathogenic germs, such as those of diphtheria and scarlet fever. It will also destroy the majority of the lactic-acid-producing bacteria. This temperature will not destroy the spore-bearing butyric and peptonizing bacteria and other varieties which under certain conditions may produce lactic acid. From 70° C. (158° F.) up the unorganized ferments will be destroyed and the milk will begin to undergo certain chemical and physical alterations which probably render it less easily digested and assimilated.

It is important to remember that when we use a low temperature (60° C.) the skim or pellicle which forms on milk heated in uncovered vessels will protect the bacteria it encloses in its meshes and prevent their destruction. Heat should therefore always be applied to the milk in closed vessels, or the milk

should be kept thoroughly mixed by agitation during the process of heating. If we wish to destroy all the lactic-acid-producing bacteria, the temperature to be employed should be not less than 75° C. (167° F.) for from twenty to thirty minutes.

When the milk supplied is highly contaminated, it must be sterilized at 100° C. (212° F.) for at least thirty minutes. If it is not possible to preserve the milk at a low temperature, more especially during hot weather when bacteria multiply so rapidly, it will be safer to repeat the process of heating every six hours. Whatever disadvantages this degree of heat may entail are more than offset by the advantage of destroying all the bacteria with which the milk is infected. Such milk, even after sterilization, should not be employed for the infant's use unless milk of a better quality cannot be obtained; for we know that the spores of the peptonizing bacteria are not destroyed even by temperatures as high as 110° C.; and should conditions favorable for their development be present, the peptonizing bacteria may multiply in apparently sterile milk and prove a grave source of danger for the infant.

CHAPTER XIII.

METHODS FOR THE HOME MODIFICATION OF MILK.

THERE are two methods of procedure available for the physician who proposes to feed a child with milk modified at the home. Either he may prepare and modify his mixture according to the clinical evidence afforded by the state of the child's digestion and nutrition, disregarding the percentages of the ingredients, or he may begin by the administration of a formula representing the percentages of fat, sugar, and proteids suitable for a given age and weight, altering them at will as the needs of the case demand, but always having at least an approximate idea of the strength of the food administered. The first method is empirical and easy of execution; the latter is quite as successful and much more satisfactory. A good example of the former method is the mixture of John Forsyth Meigs, consisting of equal parts of barley-water, lime-water, milk, and cream, sweetened. We know that it contains about two per cent. of proteids and four per cent. of fat, and we can vary the proportions of the different ingredients from time to time to meet the clinical indications. Success in infant feeding, then, depends quite as much on the ability to correctly interpret clinical phenomena as on the selection of the method, provided the plan of feeding adopted be not too rigid to allow for the wide variations in the digestive capacity of the infant.

In order to make even the simplest calculations we must be familiar with the percentages of the different ingredients in whole milk. It is safe to assume that milk of good quality will contain from three and a half to four per cent. proteids, four per cent. fat, four and a half per cent. sugar, and 0.7 per cent. salts.* The average milk supplied in cities will contain a lower proportion of fat than the above, varying from three to

* See page 326.

four per cent. The simplest method of feeding is to dilute milk with water or barley-water and add sugar; examples of this are Biedert's milk formulæ and the Heubner-Hoffmann Mixture. To ascertain the strength of our milk mixture we divide the percentages of the different ingredients by the degree of dilution employed. If we add two parts of water to one of milk, we dilute the milk three times and must divide by three; one part of milk to three of water gives us a divisor of four, etc. The simplest method for the estimation of sugar is to ascertain what percentage of lactose must be added to compensate for the degree of dilution and to make a sugar solution containing this percentage. For instance, if we dilute good milk four times, our mixture will contain about one per cent. proteids, one per cent. fat, and one per cent. sugar. To provide six per cent. sugar in the food we therefore use a five per cent. sugar solution for our diluent, made by dissolving one ounce of sugar (lactose) in twenty ounces of water. To provide seven per cent. sugar a six per cent. solution of lactose is made by adding one ounce of lactose to sixteen and two-thirds ounces of water. For practical purposes we may estimate that three level tablespoonfuls of milk-sugar equal one ounce, and one and a half even teaspoonfuls equal one drachm. If we use granulated sugar, two level tablespoonfuls equal one ounce and one even teaspoonful equals one drachm. For greater accuracy receptacles of known capacity must be procured. The addition of starchy decoctions, such as barley-, rice-, or oatmeal-water, adds very small amounts of proteids and fat and about one and a half per cent. of starch to the mixture. The sugar solution may be made with such decoctions instead of plain water. Enough must be prepared each morning to supply the total quantity needed during the day; during the summer months it will be safer to prepare our sugar solution twice a day to insure its freshness.

Since it is impossible by simple dilution of milk to obtain at the same time a sufficiently low proportion of proteids and

a sufficiently high proportion of fat, it becomes necessary to add fat to the diet for the great majority of cases. Cream resembles the fat of mother's milk more closely than any other substitute (such as butter, cod-liver oil, etc.), and since it is also, when fresh, more readily digestible than these other forms of fat, it should be employed for the purposes of infant feeding. The use of cream is associated with manifest objections. It is almost sure to be contaminated with bacteria,—in commercial gravity cream bacterial decomposition may be well advanced during the summer months,—it is very commonly adulterated by "cream thickener" or, worse, by preservatives, and, finally, the percentage of butter fat can rarely be known with accuracy. The importance of obtaining cream that is fresh and clean can scarcely be overestimated. During the hot weather of our American summers even the best cream sours very readily. Unless we can obtain it from a thoroughly reliable dealer, and unless we can be sure that it will be kept at a sufficiently low temperature (from 45° to 50° F.) until it is used, it is better to discard the use of cream altogether during the summer months. Whenever possible, the physician should acquaint himself personally with the methods in use at the dairy from which the milk and cream for the infant's diet are procured, since it is only thus that he can make sure that the cream is fit for use (unless he can obtain "certified milk"). During the summer months he should employ only freshly centrifugated cream, or gravity cream which has been cooled immediately after milking and kept below 50° F. during the time it is raising.

There still remains to be decided the question: How much fat is present in the cream we are using? Chapin's and Holt's tables give us estimates of the cream in top milk and will be discussed later. We have no means of knowing the exact percentage of fat in ordinary gravity or centrifugal cream, unless the dealer is willing to furnish a fat analysis. Commercial cream usually contains from twelve to sixteen per cent. of

butter fat; this variation is so great that it renders accuracy in the calculation of formulæ impossible. If we wish to know exactly how much fat we are giving the child, analysis of the cream becomes indispensable. Eight per cent., twelve per cent., and sixteen per cent. cream may be used in preparing our mixtures, also centrifugal cream containing still higher fat percentages. The higher the proportion of fat the lower will be the proportion of the other ingredients.

The following table has been used as a basis for making various formulæ, such as Westcott's, Baner's, etc. In his latest edition Holt states that the figures for the proteids are too high (see page 131).

	Fat. Per cent.	Proteids. Per cent.	Sugar. Per cent.	Salts. Per cent.
Whole milk or four per cent. cream gives	4	4.00	4.50	0.70
Eight per cent. cream gives	8	4.00	4.40	0.70
Twelve per cent. cream gives	12	3.80	4.20	0.64
Sixteen per cent. cream gives	16	3.60	4.00	0.60
Twenty per cent. cream gives	20	3.20	3.80	0.55
Thirty-two per cent. cream gives	32	2.80	3.20 (?)	0.40 (?)

By simple dilution of cream with a sugar solution of the desired strength we can prepare various mixtures of high fat content. For instance, by mixing one part of twelve per cent. cream and three parts of water we get: fat three per cent., proteids 0.90 per cent., sugar 1 per cent., and salts 0.15 per cent. The sugar-water should then be of five per cent. strength to give a total of six per cent. in our mixture. By mixing one part of eight per cent. cream with three parts of five per cent. sugar solution we get: fat two per cent., proteids one per cent., sugar six and one-tenth per cent., and salts 0.17 per cent. An eight per cent. cream can be obtained by mixing one part of sixteen per cent. gravity cream and two parts of whole milk, or one part of twenty per cent. centrifugal cream and three parts

of whole milk. A twelve per cent. cream can be made by mixing two parts of sixteen per cent. gravity cream and one part of whole milk, or equal parts of twenty per cent. centrifugal cream and whole milk (Holt).

These simple dilutions of cream with sugar solution are easy to prepare and will prove serviceable in many cases. We may raise one objection to them,—namely, that the proportion of fat and proteids must be increased and decreased together, since the ratio of fat to proteids, using eight per cent. and twelve per cent. cream, must be either two to one or three to one. To meet this objection we must employ either milk or whey in preparing our mixtures. Egg albumin has not proved a satisfactory substitute for the proteids of milk, except as a temporary expedient in cases of digestive disturbance when all milk must be withheld.

Various mathematical formulæ have been devised for estimating the quantity of whole milk and cream required to give us definite milk formulæ. The first of these was published by Thompson S. Westcott, of Philadelphia, in January, 1898; following this, in March, 1898, William L. Baner, and in May, 1898, Henry L. Coit published their methods. In March, 1899, F. Lewis Taylor generalized the previous calculations; "his formulæ must be accepted as the groundwork of every system of calculation for percentage formulæ" (Westcott). Shriner has also devised a method of calculating percentages similar to that in use at the Walker-Gordon Laboratory. HENRY L. COIT, in the *Archives of Pediatrics* for May, 1898, describes his method for the home modification of cow's milk, using a decinormal cream solution for the fat, a saccharated skimmed milk solution for the proteids not in the cream, and a standard sugar solution for the lactose not in either of the above. The practical application of this method is difficult.

BANER'S formulæ for the home modification of milk, published in the *New York Medical Journal*, March 12, 1898, are simple and easily remembered.

Given:

The quantity desired in ounces	Q
The desired percentage of fat	F
The desired percentage of sugar	S
The desired percentage of proteids	P

To find (in ounces):

Cream (16 per cent.) .... $= \frac{Q}{12} \times (F - P)$

Milk............................ $= \frac{Q \times P}{4} - C$

Water .... $= Q - (C + M)$

Lactose .... $= \frac{(S - P) \times Q}{100}$

If 20 per cent. centrifugal cream were used, the denominator would be 16.

If 12 per cent. were used, it would be 8.

Example.—To provide twenty-four ounces of a mixture containing one per cent. proteids, three per cent. fat, and six per cent. sugar:

Cream (16 per cent.) $= \frac{24}{12} \times (3 - 1) = 2 \times 2 = 4$ ounces

Milk .... $= \frac{24 \times 1}{4} - 4 = 6 - 4 = 2$ ounces

Diluent............ $= 24 - (4 + 2) = 24 - 6 = 18$ ounces

Sugar .... $= \frac{(6 - 1) \times 24}{100} = \frac{5 \times 24}{100} = 1\frac{1}{5}$ ounces

Thompson S. Westcott,[197] in an elaborate monograph on the scientific modification of milk, published in *International Clinics,* October, 1900, has considered at some length the question of milk modification by mathematical formulæ. We have selected only those which are adapted to general use, and must refer the reader to the original article for more extensive knowledge on the subject.

To determine the quantities of cream, milk, lactose, and

water for a given formula: C = cream, M = milk, F = fat, P = proteids, L = lactose, T = total quantity, S = sugar percentage desired.

$$C = \frac{(F - P)\,Q}{8.2\ (12\ \%\ \text{cream})\ \text{or}\ 12.4\ (16\ \%\ \text{cream})\ \text{or}\ 16.8\ (20\ \%\ \text{cream})}$$

$$M = \frac{QF}{4} - 3\ C\ (12\ \%)\ \text{or}\ 4\ C\ (16\ \%)\ \text{or}\ 5\ C\ (20\ \%)$$

$$L = \frac{QS - 4.3\,(M + C)}{100}$$

If twenty ounces of a mixture be desired, containing three per cent. fat, six per cent. sugar, and two per cent. proteids, using sixteen per cent. cream, the formula would read:

$$C = \frac{(3 - 2)\,20}{12.4} = \frac{20}{12.4} = 1.5\ \text{ounces}$$

$$M = \frac{20 \times 3}{4} - 4 \times 1.5 = \frac{60}{4} - 6 = 9\ \text{ounces}$$

$$L = \frac{20 \times 6 - 4.3\ (9 + 1.5)}{100} = \frac{120 - 45}{100} = \tfrac{3}{4}\ \text{ounce}$$

Conversely, in order to determine the percentage of ingredients in any combination of cream, milk, and sugar, Westcott suggests the following:

To find percentage of fat:

$$\frac{C}{Q} \times 16\ (\text{or}\ 12) = \text{fat percentage from cream}$$

$$\frac{M}{Q} \times 4 = \text{fat percentage from milk}$$

Sum of these = total fat percentage in mixture

To find percentage of proteids:

$$\frac{C}{Q} \times 3.6\ (16\ \%)\ \text{or}\ 3.8\ (12\ \%) = \text{proteid percentage from cream}$$

$$\frac{M}{Q} \times 4 = \text{proteid percentage from milk}$$

Sum of these = total proteid percentage in mixture

$$\text{Sugar percentage} = \frac{100\ L + 4.3\ (M + C)}{Q}$$

For instance, taking the same mixture as above determined,—namely, one and a half ounces of sixteen per cent. cream, nine ounces of milk, three-quarters of an ounce of lactose, and nineteen and a half ounces of water:

$$\frac{1.5}{20} \times 16 = 1.2$$

$$\frac{9}{20} \times 4 = \underline{1.8}$$

3.0 per cent. total fat

$$\frac{1.5}{20} \times 3.6 = .27$$

$$\frac{9}{20} \times 4 = \underline{1.80}$$

2.07 per cent. total proteids

$$\frac{100 \times .75 + 4.3 \times 10.5}{20} = \frac{75 + 45.15}{20} = 6 \text{ per cent. sugar}$$

Westcott has also published formulæ for mixtures of separated milk and centrifugal cream. Unless we wish to obtain either very low or very high fat percentages, mixtures of cream and whole milk are all that is necessary.

Edward Hamilton, in the *American Journal of Obstetrics*, October, 1901,[250] describes a method based on the fact that ordinary cream, milk, and skimmed milk contain relatively the same amount of proteids and salts, and that cream is simply a superfatted milk. If we multiply the quantity of milk mixture to be used by the percentage of fat desired and divide by the percentage of fat in the cream used, we obtain the amount of cream; if we multiply the quantity of milk mixture by the percentage of proteids desired, divide by four (the percentage of proteids in skimmed milk), and subtract from this result the amount of cream previously determined, we obtain the amount of skimmed milk needed. The quantity of the milk mixture less the amount of cream and skimmed milk will equal the amount of the diluent to be used. Three drachms (one level tablespoonful) of lactose must be added to each ten ounces of the mixture; lime-water or soda may be used to reduce the acidity.

Example.—Forty ounces of mixture desired: fat four per cent., sugar seven per cent., proteids two per cent. (sixteen per cent. cream to be used).

$40 \times 4 \div 16 = 10$ ounces cream

$40 \times 2 \div 4 = 20 - 10 = 10$ ounces of skimmed milk

$40 - 20 = 20$ ounces diluent

Sugar = four level tablespoonfuls

Lime-water q.s.

This method seems to be an adaptation of Baner's formula, using skimmed milk in place of whole milk.

The advantages of adding whey to milk or cream mixtures have already been considered. We are enabled to combine the digestible whey-proteids with the proteids and fat of cream or milk, thereby greatly lowering the proportion of coagulable to non-coagulable proteids.

Practically, three methods may be employed in the preparation of whey.

1. Simple coagulation with rennet or essence of pepsin, avoiding subsequent agitation of the curd, the fluid being allowed to separate solely by gravity. Whey so prepared will contain practically all the salts and sugar of the milk, a minimum of casein, a small amount of fat, and all of the soluble albumin (Monti). Its composition may be estimated at: whey-proteids from 0.85 to one per cent., fat 0.33 to 0.50 per cent., sugar 4.50 per cent., salts 0.18 per cent.

2. After coagulation the curd may be thoroughly beaten until disintegrated and the fluid contents expressed by straining forcibly through several layers of cheese-cloth. This is again strained to remove the fine casein flakes which were forced through. This preparation will contain more fat (perhaps as much as one per cent.) and slightly more casein than whey separated by the preceding method.

3. Like the second method, except that the casein flakes are not strained. A small amount of casein may thus be administered in a readily assimilable form.

An objection to the use of whey is the expense of preparing it, but if we remove the top milk from a quart bottle, we can usually obtain enough whey from what remains for the purpose of dilution. Before adding whey to cream or milk, it should be heated to 65° C. (150° F.) in order to destroy the rennet enzyme. At 70° C. (160° F.) the soluble albumin begins to coagulate.

Rotch says that it is cheaper to prepare whey from fat-free milk.

König's analysis of whey (proteids 0.86 per cent., fat 0.32 per cent., sugar 4.79 per cent., salts 0.15 per cent.) was used by Westcott in preparing the following tables of whey-cream mixtures. Other authorities have found as high as one per cent. of whey-proteids, while Monti asserts that whey contains as high as one per cent. fat. This percentage of fat is probably obtained by a method similar to No. 2.

Quantity of cream to be used in a twenty-ounce mixture with whey. ....to give	Fat. Per cent.	Proteids. Per cent.
Twenty per cent. cream.		
0.70 ounce	1.00	0.94
1.71 ounces	2.00	1.06
2.72 ounces	3.00	1.18
3.74 ounces	4.00	1.30
Sixteen per cent. cream.		
0.87 ounce	1.00	0.98
2.14 ounces	2.00	1.15
3.42 ounces	3.00	1.32
4.69 ounces	4.00	1.50
Twelve per cent. cream.		
1.16 ounces	1.00	1.03
2.88 ounces	2.00	1.28
4.59 ounces	3.00	1.53
6.30 ounces	4.00	1.79

Eight per cent. cream.		
1.77 ounces	1.00	1.13
4.38 ounces	2.00	1.53
6.98 ounces	3.00	1.92
9.58 ounces	4.00	2.32
Four per cent. cream (whole milk).		
3.69 ounces	1.00	1.44
9.13 ounces	2.00	2.29
14.56 ounces	3.00	3.15
20.00 ounces	4.00	4.00

The only objection to the use of such tables is that they can scarcely be memorized and may not be available when needed. The simplest method of determining the proportions in a whey-cream mixture is to add the percentages of the different ingredients, dilute with plain water or barley-water, and divide by the degree of dilution.

	Fat. Per cent.	Proteids. Per cent.	Sugar. Per cent.	Salts. Per cent.
Sixteen per cent. cream (one part) =	16.00	3.60	4.00	0.60
Whey (one part) =	0.50	1.00	4.50	0.18
Water (three parts)	....	....	....	....
Total (five parts) =	16.50	4.60	8.50	0.78

Diluting with three parts of water and dividing by five, we get a mixture composed as follows: fat 3.3 per cent., proteids 0.92 per cent., sugar 1.70 per cent., and salts 0.15 per cent. We must then add enough sugar to our mixture to bring the sugar percentage up to six or seven. For instance, if we wish to prepare a whey-cream mixture containing 0.92 per cent. proteids, 3.3 per cent. fat, 0.15 per cent. salts, and six per cent. sugar, we must dilute with a seven per cent. sugar solution. The amount of sugar present in the cream will then be represented by four, that in the whey by 4.5, and that in three

parts of seven per cent. sugar solution by twenty-one ($3 \times 7 = 21$). Adding these figures, we obtain 29.50, which must be divided by the degree of dilution (five) to give us the amount of sugar present,—almost six per cent.

Another method of bringing up the sugar percentage to the desired strength is simply to add sugar to the total quantity of the mixture. For example, twenty-five ounces of the above mixture, when prepared with plain water, will contain 1.7 per cent. sugar. By adding one ounce of lactose to twenty-five ounces of water we increase the sugar percentage of our mixture by four ($4 + 1.7 = 5.7$ per cent. sugar).

To prepare two ounces of a whey-cream mixture containing 1.5 per cent. proteids, 1.5 per cent. fat, and five per cent. sugar, add two drachms of eight per cent. cream to fourteen drachms of whey. We thus dilute our cream eight times, and must divide by eight to obtain the percentage of fat, proteids, and sugar represented by the cream.

	Fat. Per cent.	Proteids. Per cent.	Sugar. Per cent.
Cream (eight per cent.) contains......... 8)	8.00	4.00	4.00
	1.00	0.50	0.50
Whey contains........................	0.50	1.00	4.50
Total...........................	1.50	1.50	5.00

In a recent publication [254] Thompson S. Westcott presents new formulæ for the preparation of whey, cream, and whole milk mixtures. In the newer method the proportions of casein and lactalbumin can be altered at will. He has adopted Van Slyke's figures of four to one for the proportion of caseinogen to lactalbumin (*Journal of the American Chemical Society*, November, 1893, p. 605); lactalbumin therefore equals one-quarter casein. Westcott estimates on the basis of one per cent. whey-proteids in whey (Wisconsin Agricultural Experiment Station). The significance of the symbols used in the formulæ is as follows:

F = desired fat percentage
K = desired casein percentage
A = desired lactalbumin percentage
S = desired sugar percentage
W = desired diluent
C = quantity of cream in ounces
M = quantity of milk in ounces
Wh = quantity of whey in ounces
L = quantity of dry lactose in ounces
Q = total quantity of mixture
P' = percentage of combined proteids supplied by milk and cream
A' = percentage of lactalbumin supplied by whey

Therefore, $$P' = K + \tfrac{1}{4} K$$
and $$A' = A - \tfrac{1}{4} K$$

Having found the value of A', the quantity of whey is easily calculated by the proportion:

$$A' : 1.00 :: Wh : Q$$

Whence $$Wh = \frac{A'}{1.00} \times Q \text{ or } Wh = A' \times Q$$

Example.—Required a mixture of forty ounces containing fat three per cent., casein 0.80 per cent., lactalbumin 0.50 per cent., sugar six per cent. (sixteen per cent. cream to be used).

$$P' = .80 + .20 = 1.00$$
$$A' = .50 - .20 = .30$$
$$\therefore Wh = .30 \times 40 = 12 \text{ ounces}$$

By substituting in his regular formula (page 302) the value of P' instead of P, we obtain:

$$C = \frac{(3.50 - 1.00)\ 40}{12.4} = 8 \text{ ounces}$$

and

$$M = \frac{3.50 \times 40}{4} - 4 \times 8 = 3 \text{ ounces}$$

$$W = 40 - (8 + 3 + 12) = 17 \text{ ounces}$$

The amount of lactose is determined by the formula:

$$L = \frac{Q \times S - (4\ C + 4.4\ M + 4.8\ Wh)}{100}$$

$$\therefore L = \frac{40 \times 6 - (4 \times 8 + 4.4 \times 3 + 4.8 \times 12)}{100} = 1\tfrac{3}{8} \text{ ounces}$$

Ordinarily, sixteen per cent. cream will furnish sufficient fat; rarely twenty per cent. cream will be needed. The proportion of lactalbumin can never exceed one per cent. and will practically always fall below this. The range of variation of the casein, lactalbumin, and fat has been calculated for different strengths of cream. In the main they may be stated as follows: from one to four per cent. fat, from 0.07 to 3.20 per cent. casein, and from 0.017 to 0.95 per cent. lactalbumin.

Conversely, to determine the proportions of fat, casein, and lactalbumin in a given mixture, we may use the following:

For fat percentage:

$$\frac{C}{Q} \times (16 \text{ or } 20 \text{ or } 32) = \text{fat percentage from cream}$$

$$\frac{M}{Q} \times 4 = \text{fat percentage from milk}$$

Sum of these = fat percentage in the modification

For caseinogen percentage:

$$\frac{C}{Q} \times (3.6 \text{ or } 3.2 \text{ or } 2.8) \times \frac{4}{5} = \text{caseinogen percentage from cream}$$

$$\frac{M}{Q} \times 4 \times \frac{4}{5} = \text{caseinogen percentage from milk}$$

Sum of these = caseinogen percentage in the modification

For lactalbumin percentage:

$$\frac{C}{Q} \times (3.6 \text{ or } 3.2 \text{ or } 2.8) \times \frac{1}{5} = \text{lactalbumin percentage from cream}$$

$$\frac{M}{Q} \times 4 \times \frac{1}{5} = \text{lactalbumin percentage from milk}$$

$$\frac{Wh}{Q} \times 1 = \text{lactalbumin percentage from whey}$$

Sum of these = lactalbumin percentage in modification

$$S = \frac{100\ L + 4\ C + 4.4\ M + 4.8\ Wh}{Q}$$

NOTE.—Westcott includes all the "whey-proteids" under the heading "lactalbumin."

Top-Milk Mixtures.

Chapin's method was described in the *New York Medical Journal,* February 23, 1901, and may be summarized as follows:

The results of a large number of analyses of top milk by the Babcock method enable us to divide milk into three classes, the poor, the medium, and the rich, in which the percentages of fat average three, four, and five respectively. When bottled milk is allowed to stand undisturbed, most of the cream will rise within from sixteen to twenty hours; the fat in the skimmed milk will vary from 0.5 to 1.5 per cent.

Chapin's table represents the varying percentages of fat in the upper sixteen ounces of a quart bottle of milk which has stood for at least twelve hours.

Fat in whole milk	3 per cent.			4 per cent.			5 per cent.		
Fat in skimmed milk	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
Fat in top six ounces.....	13.8	11.6	9.5	19.1	17.0	14.8	24.5	22.3	20.1
Fat in top seven ounces ..	11.9	10.1	8.3	16.5	14.7	12.9	21.0	19.4	17.5
Fat in top eight ounces...	10.5	9.0	7.5	14.5	13.0	11.5	18.5	17.0	15.5
Fat in top nine ounces ...	9.5	8.1	6.8	12.9	11.7	10.4	16.5	15.2	14.0
Fat in top ten ounces	8.6	7.4	6.3	11.7	10.6	9.5	14.9	13.8	12.7
Fat in top eleven ounces..	7.8	6.8	5.9	10.7	9.7	8.8	13.6	12.6	11.7
Fat in top twelve ounces..	7.2	6.3	5.5	9.8	9.0	8.1	12.5	11.7	10.8
Fat in top thirteen ounces	6.7	6.0	5.2	9.1	8.4	7.6	11.6	10.8	10.1
Fat in top fourteen ounces	6.3	5.6	5.0	8.5	7.8	7.2	10.7	10.1	9.5
Fat in top fifteen ounces..	5.9	5.3	4.7	8.0	7.4	6.8	10.1	9.5	9.0
Fat in top sixteen ounces.	5.5	5.0	4.5	7.5	7.0	6.5	9.5	9.0	8.5

If Chapin's method is to be used, and it is impossible to obtain analyses of the fat in the whole milk and skimmed milk, the physician must be content with approximate percentages: accuracy is out of the question. The market milk furnished by the smaller dealers to the poorer classes probably rarely

exceeds the legal limit of three per cent. fat. The milk from the better class of dairies will contain as much as four per cent. fat or even higher. The high-grade product of Alderney and Jersey cattle will often equal four and a half or five per cent.

Assuming then, for example, that we can obtain a medium milk, and taking the middle column of Chapin's medium milk table as the safest average, we then divide this figure by the degree of dilution employed in order to obtain the percentage of fat in our mixture. We assume, for facility in calculation, that the percentages of proteids and sugar in our cream are four each (actually they are somewhat lower in cream of high fat percentage). For instance, the upper nine ounces of medium milk (middle column) contain 11.7 per cent. fat, four per cent. sugar, and four per cent. proteids. To prepare thirty-six ounces for the day's supply we add to these nine ounces twenty-seven ounces of a five per cent. sugar solution, thus diluting the top milk four times; dividing by four, we get this result: fat 2.92 per cent., proteids one per cent., and sugar one per cent. plus five per cent. (in the diluent) equals six per cent. If we mix the upper ten ounces of medium milk (middle column) with twenty ounces of a five per cent. sugar solution, and divide the percentages by three, our mixture will contain: fat 3.53 per cent., proteids 1.33 per cent., and sugar 1.33 per cent. plus five per cent. (in the diluent) equals 6.33 per cent.

To make four per cent. sugar solution add one ounce of lactose to twenty-five ounces of water; to make five per cent. sugar solution add one ounce of lactose to twenty ounces of water; to make six per cent. sugar solution add one ounce of lactose to sixteen and two-thirds ounces of water.

Chapin has devised a dipper of one ounce capacity which can easily be inserted into the neck of the ordinary quart milk-bottle. The obvious advantages of this method are that the consumer obtains a product in which the dangers of contamina-

tion from handling are reduced to a minimum, that the necessity for employing commercial cream is avoided, and that the cream and milk in our mixture are obtained from the same source.

In order to test more fully the range of variations of the fat in top milk, the authors decided to obtain a number of analyses of the product of a single first-class dairy.

It seemed reasonable to suppose that the variations would be less than those found in Chapin's experiments with milk from different sources. The results, however, showed that in a whole milk with a fat percentage varying from five to 5.5 the amounts of fat in the upper ounces showed in many instances as great or greater variations than Chapin's figures indicate. Without daily tests absolute accuracy is therefore impossible with top-milk mixtures.

When we consider, however, the frequent and decided variations in the fat content which occur in mother's milk without harm to the healthy infant, it seems probable that moderate variations in the fat content in a cow's milk mixture, when the child has become accustomed to the digestion of cow's milk, will probably rarely lead to digestive disturbances, provided the milk is pure and the child is carefully fed.

The tests we have made fairly establish a working average for the milk of one dairy during a certain period (from January to March). We hope to continue them during the remainder of the year, and also to establish a ratio between the fat in the whole milk and the fat in the top milk in the same bottle. When this ratio has been determined, an occasional test of the whole milk will show whether the proper proportion of fat is being maintained.

The tests were made for us by Mr. Walter Cuthbert, a graduate in chemistry, whom we were fortunate enough to interest in this subject. He controls in large part the output of the Spotswood Dairy Farm at Broad Axe, Pennsylvania.

The whole-milk tests show a uniformly high percentage of

fat; the uppermost ounces from such a milk are therefore not available for infant feeding, as any reasonable dilution of the fat would bring the proteid percentage much below what is needed. This difficulty could be obviated by dilution with skimmed milk or whole milk, using the top milk only as a rich cream. As one of the primary objects of the top-milk method is to obtain the fat and proteids from the same supply, it is better to remove the upper ten ounces or more even if this entire amount is not needed. The larger amounts will also contain practically all the fat from that quart, and the variations will depend on the amount of fat in the whole milk, while the proportion of this ingredient in the upper two to six ounces depends also on the length of time the cream has been raising, the temperature, physical condition of the fat-globules, etc. For these reasons our tests have mainly been made with the larger amounts of top milk.

In making the fat tests Mr. Cuthbert employed the Leffmann-Beam method described on page 342. The quart bottles were selected entirely by chance. The cream had been raising from fourteen to sixteen hours and the cream layer was therefore fully formed.

In removing the top milk we employed a cone-shaped dipper constructed according to J. C. Gittings's design by V. Clad & Sons. The cone-shaped base permits the dipper to pass easily through the cream layer without disturbing it.

The first ounce was partially removed by pouring into the dipper, which could then be inserted without causing the cream to overflow. It was a noticeable fact that the actual measurement of the cream layer in all the bottles tested varied only from 3.4 to four inches. The depth of this layer depends on

the shape of the bottle, the length of time the cream has been raising, and the temperature. The first two conditions being the same in all our tests, we found the following variations dependent on the weather conditions, irrespective of the fact that the milk was kept well iced.

Weather conditions.	Inches of cream in one quart bottle.
Moderate and warm	3.70 average
Moderate and freezing	3.75 to 4.00
Continuous freezing	4.00 average

TABLE OF FAT PERCENTAGES IN TOP MILK.

Whole milk.	Upper sixteen ounces.	Fourteen ounces.	Twelve ounces.	Ten ounces.	Eight ounces.	Six ounces.	Four ounces.
5.0	9.6	10.2	12.3	14.4	18.6	21.6	23.4
5.0	9.6	10.5	12.6	14.4	18.9	21.6	23.7
5.0	9.6	10.8	13.2	14.4	19.2	22.5	24.3
5.1	9.6	10.8	13.2	15.0	19.8	22.8	24.3
5.1	9.6	10.8	13.2	15.0	19.8	....	....
5.1	9.9	11.4	13.5	15.0	20.1	....	....
5.2	10.2	11.4	13.5	15.6	....	....	....
5.2	10.2	11.7	13.5	15.6	....	....	....
5.2	10.2	11.7	13.6	15.6	....	....	....
5.3	10.2	11.7	13.8	15.9	....	....	....
5.3	10.4	11.8	13.8	16.2	....	....	....
5.3	10.5	12.0	13.8	16.2	....	....	....
5.4	10.5	12.0	13.8	16.2	....	....	....
5.4	10.8	12.0	13.8	16.8	....	....	....
5.4	10.8	12.0	14.1	17.1	....	....	....
5.4	....	13.2	....	....	....	....	....
5.5	....	13.2	....	....	....	....	....
Average.	Average.	Average.	Average.	Average.	Average.	Average.	Average.
5.23	10.11	11.6	13.44	15.56	19.40	22.12	23.92

As we will have to dilute the top milk at least three times, the possible error in the fat percentage of our mixture, according to this table, will be reduced by this dilution so as to fall below 0.5,—rarely as high as this. For example, the column of fat values for the upper fourteen ounces shows the greatest variations,—from 10.2 to 13.2. If we divide the average of this column (11.6) by 3 we get 3.9 fat. The possible error will therefore be: $10.2 \div 3 = 3.4$ and $13.2 \div 3 = 4.4$, figures respectively .5 above and .5 below the average. Although this is far from strict accuracy, it is probably less of an objection than might be supposed.

Condensed Milk.

No preparation of cow's milk enjoys a wider popularity among the laity, especially among the poorer classes, than condensed milk. Few physicians of wide experience have failed to note that many infants have not only lived but thrived upon an exclusive diet of condensed milk during the early months of life. Condensed milk must be well diluted before it is given to the infant. If we add to it from eight to twelve times its amount of water, we reduce its proteid and fat content to one per cent. and less, while the proportion of sugar becomes from five to six per cent. This amount of sugar is sufficient, but the proportion of proteids and fat is too low, especially the latter.

One possible explanation for the child's apparent thriving and gain in weight is that a "teaspoonful" of the condensed milk is in reality almost two teaspoonfuls, since almost as much of the thick syrupy milk adheres to the bottom and edges of the spoon as the spoon contains. We actually, then, administer an excess of sugar, a proper proportion of proteids, and a deficient amount of fat; the sugar can be converted into fat and give the child its plump appearance; the proteids are presented in an easily digestible form, since they clot in much finer curds than raw cow's milk; while the fat, being in fine emulsion, is also usually well utilized. Clinical observation

has proved, however, that a prolonged exclusive diet of condensed milk often results in the development of such nutritional disorders as anæmia, rickets, scurvy, and athrepsia. Moreover, the infant, while apparently healthy, lacks vital resistance and easily succumbs to the various infectious diseases which he may contract. The deficiency in fat, the excess of sugar, and the "lack of freshness" in condensed milk are probably all causative factors in these results.

There is no doubt that the judicious employment of condensed milk meets certain indications in infant feeding,—namely, where persistent, intelligent modifications of cow's milk have failed, and where lack of resources or of intelligent co-operation on the part of the mother prevents the adoption of more elaborate methods of feeding. As a temporary expedient, condensed milk may be administered for short periods of time to tide over emergencies, especially among the poor during the summer months, when it is difficult to obtain good milk and to keep it from spoiling.

Whenever possible, we should attempt to supplement the inherent deficiencies in a condensed milk diet by the addition of fresh cream. With such supplement the infant undoubtedly will receive sufficient nourishment to meet the demands of the organism, even for long periods of time, though it should always be our aim to revert to a diet of cow's milk as soon as opportunity offers. It is important to select those brands of condensed milk which contain high fat percentages (some as high as twelve per cent.) and to use only those which are preserved by the addition of cane-sugar. The following formulæ, based on Holt's analysis of Eagle Brand Condensed Milk, are given as examples of what percentages may be obtained with mixtures of condensed milk and cream.

When we desire to increase the proteid percentage without appreciably increasing the fat, we can use whey to replace a portion of the water in the diluent, taking care not to increase the sugar excessively.

	Proteids. Per cent.	Fat. Per cent.	Sugar. Per cent.	Salts. Per cent.
I. Cream (twelve per cent.) one part.	3.8	12.00	4.2	0.64
Condensed milk one part	8.4	7.00	50.00	1.39
Water six parts..................	...	....	.....	....
8)	12.2	19.00	54.2	2.03
Average..................	1.5	2.5	6.75	0.25

			Per cent.
II. Cream (sixteen per cent.) one part. Condensed milk one part.......... Water six parts..................	=	Proteids........	1.5
		Fat............	3.00
		Sugar..........	6.75
		Salts...	0.25
III. Cream (sixteen per cent.) one part. Condensed milk one part .... Water ten parts	=	Proteids........	1.00
		Fat............	2.00
		Sugar	4.5
		Salts...........	0.16

By employing cream of higher fat percentage the proportion of fat can be increased, and by using cream of lower fat percentage the proportion of proteids can be increased.

Much less can be said in favor of the other artificial preparations of milk, such as the proprietary foods. Some of these are designed to be used with fresh cow's milk, and furnish a convenient means of beginning the administration of starch towards the end of the first year. In making a selection, preference should be given to those preparations in which the starch has been completely dextrinized.

Another class of proprietary foods are widely advertised as perfect substitutes for mother's milk when simply diluted with water. Many of them contain a large amount of starch in an insoluble form, while the casein and fat in dried form differ widely from the same ingredients in cow's milk. This class of foods should never be employed to the exclusion of cow's milk, except as a temporary expedient.

CHAPTER XIV.

PRACTICAL RULES FOR FEEDING.

One of the practical objections to the home modification of milk for infant feeding has been the length of time necessary to fully explain the process to the mother or nurse, time which few busy practitioners have to spare. The best way to obviate this difficulty is to have a printed list of directions to present to the mother. We have attempted to prepare such a list, which may be used or modified as the physician may desire. When the principles of cleanliness are once understood, the mother can easily apply them to any method of feeding, such as whey-cream mixtures, top-milk mixtures, etc.

I. The milk should be obtained in bottles which have been filled and sealed at the dairy.

II. As soon as the bottle is received it should be placed on ice until the day's food is to be prepared.

III. All utensils which are to be employed in the milk-modification should be cleansed with boiling water, if possible, just before being used.

IV. The following articles are necessary: (*a*) A jar of boiled water or freshly prepared barley-water. (*b*) A jar containing milk-sugar or granulated sugar. (*c*) A bowl containing freshly boiled water, in which stand a tablespoon, a knife, and a one-ounce dipper (for top-milk mixtures). (*d*) A freshly scalded eight-ounce glass graduate. (*e*) Two freshly scalded quart preserving jars and caps. (*f*) A bottle of lime-water. (*g*) An enamelled or glass funnel, freshly scalded.

V. When the mixture is to be prepared, the mother or nurse should thoroughly wash her hands before placing these articles upon a clean napkin. The neck and cap of the bottle

of milk (or cream) are next thoroughly cleansed with hot water. The pasteboard cap is then removed by inserting the knife under the edge. The upper half-inch of milk or cream may be removed with a spoon and discarded if the cap has been carelessly adjusted.

VI. Remove the upper —— ounces of top milk from the jar of milk with the dipper (gently pouring the first half-dipperful to allow space for the dipper to be inserted), or measure —— ounces of cream and —— ounces of whole milk (or skimmed milk) in the glass graduate. The milk and cream (or top milk), as they are measured, should be poured into one of the freshly scalded quart jars (No. I.).

VII. Dissolve —— ounces of milk-sugar (or granulated sugar) in —— ounces of boiling water (in the graduate). Pour this at once into jar No. II. and add —— ounces of boiled water (or barley-water); —— ounces of lime-water (if desired) are then added. The contents of jar No. I. are then poured into jar No. II. and thoroughly mixed. It is then tightly capped and placed on ice until ready for use.

N.B.—It is important to remember that any fluid used in the milk mixtures other than milk and cream is a diluent. The simplest method is to dilute milk and cream with water. Whatever diluents are added to our mixture, such as whey, barley-water, sugar solution, lime-water, etc., the total quantity of such diluents must be made to equal the total amount of diluent required. The sugar solution may be made with either plain water or barley-water. Holt recommends that the sugar of milk should be dissolved in boiling water. The amount of the latter should then be subtracted from the total amount of the solution.

VIII. When the infant is to be fed the jar is again agitated and the proper quantity poured into a freshly scalded feeding-bottle through a freshly scalded funnel; the nipple, also

freshly scalded, is then put on and the bottle stood in hot water until the milk feels warm to the back of the hand. Exceptionally, or in summer, the child prefers it cool. In cases of extreme gastric irritability it may be better tolerated ice-cold.

IX. Feeding-bottles should be cleansed with cold water as soon as the child has finished its meal, and kept filled with water until ready to be scalded for use. The bottles should have rounded corners so that they may be easy to clean.

X. The rubber nipples should be thoroughly cleansed on both surfaces with soap and cold water and kept in a cup of borax solution until ready to be scalded for use.

XI. The baby should be fed:

During the first month every —— hours from —— A.M. to —— P.M., with —— night feedings. —— ounces should be given at each feeding.

During the second and third months give —— ounces every —— hours from —— A.M. to —— P.M., with —— night feedings.

During the fourth and fifth months give —— ounces every —— hours from —— A.M. to —— P.M., with —— night feedings.

From the sixth to the eighth month give —— ounces every —— hours from —— A.M. to —— P.M. No night feedings.

From the ninth to the twelfth month give —— ounces every —— hours from —— A.M. to —— P.M.

XII. The infant should be held in a reclining position to be fed, and should consume the whole amount in from fifteen to twenty minutes. Where there is difficulty in breathing, the time for the meal may be lengthened. Should the infant refuse the bottle before the entire quantity is consumed, after a short interval offer the bottle again. If it is again refused, the remainder of the milk should be thrown away and the infant should not be fed again until the proper interval has elapsed.

The practice of some mothers and nurses of moistening the nipple beforehand or putting it in the mouth to test the temperature of the milk cannot be too strongly condemned.

Whenever possible, it is preferable to have separate feeding-bottles. After the total quantity for the day has been mixed and well shaken the bottles are to be filled through the scalded funnel and stoppered with sterile non-absorbent cotton. These cotton plugs should be made of sufficient size to tightly stopper the feeding-bottles. The plugs may be sterilized by steaming them for three hours in a double boiler (such as is used in most households for cooking cereals). It is more convenient to prepare a large quantity of these plugs at a time and to keep them in a scalded fruit jar, tightly capped. They will then remain approximately sterile. The stoppered feeding-bottles must be kept on ice and warmed when needed, the plug being then exchanged for a freshly scalded nipple.

If top milk is to be used, the physician should ascertain when the milk was bottled, so that the necessary time for the raising of the cream may be allowed. The milkman should be requested to avoid any agitation of the bottles which would interfere with the raising of the cream. During warm weather the milk should be delivered only after some one is about to receive it and place it at once on ice. An hour's standing on the doorstep in summer may render the milk unfit for use.

The table which follows is intended to indicate the average amounts of the milk mixture to be given at each feeding and the intervals between meals. Since these are influenced by a variety of factors, such as the condition of the digestion, the gain in length and weight, etc., the table must be considered to represent only a normal average. It is rarely advisable to furnish the mother or nurse a list of directions covering extensive periods of time, since they are only too apt to rely on them and to ignore evidences of indigestion, failure to gain in weight, etc., which require the physician's personal attention.

Age.	Interval.	Number and time of feedings.	Amount at each feeding.	Total amount.
First month	2 hours	Eight day feedings from 6 A.M. to 8 P.M. Two night feedings	1st week, 1 ounce 2d and 3d weeks, $1\frac{1}{2}$ ounces 4th week, $2–2\frac{1}{2}$ ounces	10 ounces 15 ounces 20–25 ounces
Second month	$2\frac{1}{2}$ hours	Seven day feedings from 6 A.M. to 9 P.M. One night feeding	$2\frac{1}{2}–3$ ounces	20–24 ounces
Third month	$2\frac{1}{2}$ hours	Seven day feedings from 6 A.M. to 9 P.M. One night feeding	3–4 ounces	24–32 ounces
Fourth month	3 hours	Six day feedings from 6 A.M. to 9 P.M. One night feeding	4–5 ounces	28–35 ounces
Fifth month	3 hours	Six day feedings from 6 A.M. to 9 P.M. One night feeding	$4\frac{1}{2}–5\frac{1}{2}$ ounces	32–38 ounces
Sixth to eighth month inclusive	3 hours	Six day feedings from 6 A.M. to 9 P.M. No night feedings	6–7 ounces	36–42 ounces
Ninth to twelfth month inclusive	3 hours	Five day feedings from 6 A.M. to 6 P.M.	7–9 ounces	35–45 ounces

After the third month the night feeding may be omitted, and only in exceptional cases should it be continued after the fifth month.

By "night feeding" is meant any meal after nine P.M.

It is always best to adhere as closely as possible to a given routine in regulating the intervals between meals. This applies to the healthy as well as to the sick infant. There is less danger of the interval being too long than too short; if the child is sleeping at the time for his feeding, it is best not to disturb him. The succeeding meals should be given at the proper intervals, even if not on schedule time.

It may be found that the infant will habitually oversleep; if he is healthy and gaining weight the longer interval may safely be allowed. Occasionally the infant will turn night into day by persistently oversleeping during the daytime and will want his food frequently at night. It is then necessary to waken him at proper intervals during the day and thus break up the habit.

If an infant is born underweight and shows early evidences of indigestion, it may be necessary to adhere to the two-hour intervals and to weaker dilutions for several months. These cases cannot be considered normal, since the capacity of the stomach and the nutritional demands of the organism are usually less than those of the average child. They must be studied with especial care, and no absolute rules can be laid down for their management.

Much oftener we encounter the difficulty of a too frequent desire for food. The conditions which render it advisable to increase the strength or the quantity of our milk mixture are: when the infant habitually cries after finishing his meal and continues to cry until the next feeding, when there are no signs of indigestion, and when it is impossible to find any other cause for his fretfulness. The change in the diet is particularly indicated when there is failure to gain in weight or the gain is persistently below normal. Habitual crying, however, is usually a sign of colic and indigestion and requires readjustment of the diet. Nearly all these cases show evidences of malnutrition, and their cry not only denotes pain, but also craving for a food which will satisfy the needs of their system.

The principal difficulty in the management of these cases is the enforcement of sufficiently long intervals between meals. This should rarely be less than two hours; often a longer interval may be observed with advantage. A drink of plain water or of barley-water between meals will do no harm and will often suffice to quiet the child. When we are forced to feed the child on a milk mixture containing very low proportions of proteids and fat, which are insufficient for proper nutrition and growth, it is often desirable to supplement the diet with one of the predigested foods, such as liquid peptonoids, panopepton, or predigested beef. Somatose and plasmon may also be used, but are not always well tolerated. These preparations can be given either with the meal or during the interval.

In an entirely distinct class are those infants who are particularly robust from birth, and whose weight, length, and rapidity of growth are above the normal. The food requirements of these cases may be from a month to six weeks in advance of the normal requirements of the average infant.

If the infant vomits a few minutes after finishing his meal, before curdling has occurred, either too much milk has been taken or it has been consumed too quickly. To obviate this difficulty unpierced nipples should be procured in which the aperture can be made as small as desired, or the device of Bonwill [14] may be resorted to. He inverts a small nipple into the neck of the bottle; a short nipple is then put on in the usual manner. The advantages of this method are the vigorous sucking that it demands and the length of time required for the meal. It is obviously unsuited for weak infants. When regurgitation persists in spite of these measures, it is usually safer to reduce the quantity of the food mixture, since the amount is probably in excess of the gastric capacity; or the proportion of fat or proteids may be too high (Holt) and need reduction. The propriety of pasteurization or of sterili-

zation has already been discussed (page 293). If one or the other is considered desirable, it should be done as soon as the milk is received, and the milk should then be kept on ice until the day's mixing is to be done. If separate feeding-bottles are to be used, the process may be repeated when they are filled.

During the heated term, when gastro-intestinal disorders are particularly apt to occur, great care should be exercised to avoid overtaxing the infant's digestion. If the child is taking a milk mixture of high proportions, containing from two to two and a half per cent. proteids and three and a half to four per cent. fat, it is usually a good plan to reduce the amount of fat in our mixture and to avoid increasing the proteids. With the first signs of gastro-intestinal disturbance, the proportion of both ingredients should be further decidedly reduced.

The necessity for the administration of water to the infant is a point to which attention has repeatedly been called, but its importance is apt to be overlooked both by the mother and the physician. Water should be administered between feedings, preferably about half an hour before a meal; it should rarely be iced except during the summer months. The quantity to be given will depend on the infant's individual taste.

HOLT.[183] When a child has been well started on some method of feeding and has begun to gain regularly in weight, a regular weekly report in writing may often take the place of the physician's visit. This should include only answers to certain questions,—namely: 1. Weight: gain or loss since last report? 2. Stools: frequency and general character. 3. Vomiting or regurgitation: when and how much? 4. Flatulence or colic? 5. Appetite: is the child satisfied? Does he leave any of his food? 6. Is he comfortable and good-natured? 7. How much does he sleep? 8. Date. 9. Date of last report.

Method for calculating Milk Percentage without Formulæ.

For those who experience difficulty in estimating the strength of a mixture of cream, milk, whey, sugar solution, etc., in proteids, fat, sugar, and salts, the following table has been devised. The method of calculation is simple and fairly accurate. The first column represents the number of parts or ounces in the total daily quantity of the mixture. The percentage strength of the different ingredients used must be multiplied by the number of parts used and then divided by the total number of parts, in order to ascertain the percentage strength of our whole mixture. An example is given of a milk, twelve per cent. cream, and seven per cent. sugar solution mixture.

	Parts.	Proteids.	Fats.	Sugar.	Salts.
Milk	2	2 × 4 = 8	2 × 4 = 8	2 × 4.5 = 9	2 × 0.7 = 1.4
Cream or top milk	4	4 × 3.6 = 14.4	4 × 12 = 48	4 × 4.2 = 16.8	4 × 0.64 = 2.56
Whey	..	....	....	....	....
Sugar solution	10	....	....	10 × 7 = 70	....
Diluent.—Barley- or plain water	..	....	....	....	....
Lime-water		....	....	....	....
Total	16)	22.4	56	95.8	3.96
Percentage of our mixture equals	..	1.4	3.5	6.0	0.24

NOTE.—It has been assumed that the percentage of proteids in whole milk is four; actually it will more frequently approximate 3.50. The higher figure is much more convenient for calculation, however, and can lead to no appreciable error if we recall that the actual amount of proteids present is from 0.1 to 0.3 lower than the figures indicate, according to the dilution employed.

CHAPTER XV.

ARTIFICIAL FOODS.

According to CAUTLEY,[38] proprietary foods may be classed as follows:

GROUP I. Foods prepared from cow's milk.

- (*a*) Condensed milk without added sugar.
- (*b*) Condensed milk with added sugar.
- (*c*) Peptonized milk.

GROUP II. Foods prepared from cow's milk and modified cereals; the starch unchanged or partially converted into dextrin, etc.

- (*a*) Containing much unchanged starch,—*e.g.*, Nestlé's, Anglo-Swiss, etc.
- (*b*) The starch largely converted into soluble carbohydrates, such as maltose and dextrin,—*e.g.*, Allen and Hanbury's.
- (*c*) Milk foods in which the milk has been partially peptonized or contains ferments which act on the addition of warm milk, and containing partially or entirely converted or unconverted starch,—*e.g.*, Benger's (prepared with milk), Carnrick's, Horlick's Malted Milk.

GROUP III. Foods prepared from modified cereals only.

- (*a*) The starch unchanged,—*e.g.*, Robinson's Prepared Barley, Frame's Food, Ridge's Food, Neave's Food.
- (*b*) The starch partially changed by the action of malt diastase,—*e.g.*, Savory and Moore's Food.
- (*c*) The starch completely changed,—*e.g.*, Mellin's Food, Horlick's Food.

Name of food.	Water.	Albuminoids.	Fats.	Starch.	Soluble carbohydrates.	Ash.	Gum, cellulose, etc.	Remarks.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Wheat flour	9.02	7.47	1.01	76.07	5.66	....	....	....
Wheat, baked	7.78	undetermined	0.41	67.60	14.29	....	....	Albuminous substances are more soluble
Robinson's Prepared Barley	10.10	5.13	0.97	77.76	4.11	1.93	1.33	....
Ridge's Food	9.23	9.24	0.63	77.96	5.19	0.60	....	Cane-sugar 2.20 %, grape-sugar 2.40 %, almost pure flour
Nestlé's Food	5.00	11.00	4.25	36.86	40.91	1.70	0.28	Soluble carbohydrate almost all cane-sugar
Anglo-Swiss condensed milk	6.50	10.26	4.91	29.48	46.43	2.02	0.40	Much cane-sugar
Franco-Swiss condensed milk	4.43	13.00	3.70	30.86	46.09	1.42	0.50	Much cane-sugar
American-Swiss condensed milk	5.68	10.54	5.81	30.00	45.35	1.21	0.41	Much cane-sugar
Malted milk	2.18	15.83	5.30	5.57	66.99	3.13	....	....
Wells and Richardson's Food	7.76	11.85	1.64	36.43	39.00	2.61	0.71	....
Savory and Moore's Food	8.34	9.63	0.40	36.36	44.83	0.89	0.44	Much grape- and cane-sugar
Horlick's Food	9.70	10.43	0.34	.....	76.83	2.20	0.50	....
Mellin's Food	12.37	10.07	0.18	.....	68.18	3.75	5.45	About half soluble carbohydrate is grape-sugar
Imperial Granum	8.38	14.13	1.4	76.11	1.80	0.39	....	....
Lacto-preparata	5.80	14.51	12.35	.....	63.68	3.66	....	....
Carnrick's Food	3.42	10.25	7.45	37.37	27.08	4.42	....	....

The table on page 328 is based on Leeds's analyses. These figures are subject to marked variation, as may be seen by reference to the results of other investigators. It may definitely be accepted that the proportion of their ingredients is not a constant one.

Monti [99] says that Nestlé's, Ridge's, Mellin's Food, etc., contain too little fat and proteids. They are in no sense a fit substitute for mother's milk, but may be used temporarily with good results. In the first months of life they should not form the exclusive nourishment. When the child is five months old and after weaning they are useful adjuvants. Theinhardt's Soluble Infant Food is similar to Mellin's Food.

Cautley [38] states as an axiom that proprietary foods are unnecessary for the proper feeding of infants so long as good cow's milk, cream, and sugar are available. They should never be used before the sixth month, and then only as diluents.

Starr [133] considers that proprietary foods are useful as mechanical attenuants, but unless they are prepared with milk it is questionable whether any of them can permanently meet the demands of nutrition.

Rotch [119] calls particular attention to the unreliability and lack of uniformity in the composition of artificial foods, which "vary too greatly in their analyses to keep even within the acknowledged varying limits of human milk."

J. Lewis Smith [129] considers them useful only as adjuvants.

Biedert [7] recommends the prepared foods, added to the milk mixture, after the sixth month as a good method of beginning the administration of starch. Bendix says that their only proper use is in addition to other foods, for short periods of time, and never before three months. Scurvy may undoubtedly follow their prolonged use.

Baginsky.[5] The infant foods may be used after the third month as an adjuvant to mother's milk; but the experience of all authors shows that the long-continued use of any of them causes a slight dyspepsia. Demme has observed a diminution

in the number of red corpuscles in children who are fed too early on starch.

Ashby and Wright [2] consider the artificial foods only useful temporarily, during a journey, etc., or when milk will not agree in any form. They do not readily ferment, but if used for too long a time, especially if the children are more than six months old, both rickets and scurvy are apt to ensue.

Drews and Krauss [85] have found that somatose is well digested by healthy as well as poorly developed infants. It produced a finer curd when mixed with cow's milk. Krauss found it odorless and its taste not objectionable. Small doses seemed to increase peristalsis without exciting the secretions of the intestines. It was useful in all disturbances of digestion in infants, and was especially valuable in replacing the nitrogenous loss in the organism. Wolf [156] also reports good results with somatose in the feeding of infants; it was well borne in gastro-intestinal disorders and by atrophic infants.

Condensed Milk.

Monti.[99] There are two principal varieties of condensed milk, one with and the other without sugar. To prepare the first, cow's milk with more or less sugar added to it is condensed in a vacuum. It then contains all the constituents in an unaltered form if the process is correctly carried out. Frequently, on opening the cans, we find the contents covered with a skim composed of crystallized sugar and dried milk materials, under which the milk will keep for a long time. Microscopically, we find fat-droplets intact and numerous sugar crystals. Fermentation fungi are present only when the can has been open for some time. The high sugar content is apt to be a source of digestive disturbances and a frequent cause of the failure of condensed milk as a food. It may cause rickets, furunculosis, anæmia, etc. Therefore it is only to be used temporarily during journeys, in the summer months, etc.

The second variety of condensed milk is prepared by heating

milk for a short time above 100° C. and then evaporating in a vacuum at about 60° C. to a third of its former volume. Monti has had no good results from its use.

CAUTLEY.[38] On account of the excess of sugar present in condensed milk, children fed on it become fat, flabby, and anæmic. Not enough proteids are present properly to nourish the tissues. If no other food is given, rickets, scurvy, bronchitis, and gastro-enteritis may develop. It is useful only as a temporary food when good cow's milk cannot be obtained or to tide over an emergency. It is apt to spoil after opening, it is not always sterile, and the composition of different brands is apt to vary.

ASHBY and WRIGHT[2] recommend its use for short periods of time, as it is sterile and does not curdle easily. Too prolonged use is apt to produce scurvy. It shonld be diluted in the proportion of one to eight or one to ten. Only those brands should be selected which contain plenty of fat. Some contain almost twelve per cent. Clinical experience teaches that it is sometimes retained when so-called fresh milk is vomited or gives rise to flatulence or colic.

STARR[133] considers it valuable as a temporary change of diet when travelling, or when cow's milk cannot be obtained. It contains too much cane-sugar and not enough nutrient material for the needs of a growing baby. Infants fed on it, though fat, are pale, lethargic, and flabby; they possess little resistance to disease; dentition is often delayed and rickets is likely to result. If the milk is kept too long, or the packing has been imperfect, it is liable to undergo decomposition.

FENWICK[52] makes the same criticisms as the above and calls attention to the wide variations in the percentage of fat in different brands, some containing scarcely any. He, too, advises that it should be used only temporarily.

E. W. SAUNDERS[125] points out some of the advantages of condensed milk which probably explain its popularity.

I. Bad milk cannot be condensed, and the large proportion

of sugar serves to keep it, although the bacteria are not destroyed thereby.

II. Practically, it is found that condensation produces molecular changes in casein, which are very advantageous. The curd produced by the action of rennet or acids is intermediate in size between that of mother's milk and cow's milk.

III. The fat-globules are kept in perfect emulsion, so that it is impossible to separate them in the centrifuge. Of course, the fat is greatly deficient in amount; however, this small amount of fat is more available than that of fresh milk because of its perfect emulsion and from the fact that the curd of condensed milk, in the meshes of which some of the fat is entangled, is more digestible than that of fresh milk. Saunders believes that condensed milk should never be used for any length of time without being fortified by cream or cod-liver oil. In addition, he makes a plea for dairy hygiene, the immediate cooling of fresh milk, and the maintenance of a low temperature until it is used.

George Carpenter [36] declares that Swiss cows are more subject to tuberculosis than other breeds, the average being about eighty-five per cent. Swiss condensed milk is prepared by evaporating *in vacuo*, so that it is not sterilized. The completed product is therefore liable to contain tubercle bacilli in an active state.

Peptonized Milk.

Cautley [38] considers peptonized milk valuable for temporary use because of its ease of digestion. It should not be continued for a long period, since it does not furnish the physiological stimulus to the natural secretions. The peptones and albumoses which it contains may cause diarrhœa. A certain amount of intelligence is necessary for its proper preparation.

Ashby and Wright.[2] Clinical experience has proved its undoubted value. Partially peptonized milk curdles less readily than raw milk and the curd is softer. It must not be

given for too long a period as the sole food, lest scurvy develop. Generally speaking, it is more useful in gastric than in intestinal affections.

ROTCH.[119] "Peptonized milk, as a food for the young infant, consists of too large an amount of digested proteids, too little sugar, and a very large over-proportion of mineral matters." It may be of use to tide over a period of difficulty until the infant's stomach has recovered its digestive power, but the indications for its employment may be met by a proper regulation of the proteids in the child's food in a more rational manner. The infant's stomach is intended to digest proteids and not to have the proteids digested for it.

STARR.[133] When properly prepared, peptonized milk presents great advantages in that the necessity to use lime-water, barley-water, and other starchy attenuants is done away with. The return to the ordinary milk diet can be made gradually by diminishing the time of the artificial digestion of the milk until pure milk can be again used. It presents the albuminoids in a minutely coagulable and digestible form. It has an alkaline reaction, contains the proper proportion of lactose, salts, and fat, and if only partially peptonized is not bitter to the taste.

FENWICK [52] thinks that its prolonged use results in enfeeblement of the digestive organs of the infant, and may lead to anæmia, rickets, and symptoms allied to scurvy.

APPENDIX.

A. Richmond. The composition of Peptonized Milk (undiluted) is given as follows by Vieth:

	Per cent.		Per cent.
Water	89.20	Albumin	0.07
Fat	3.41	Albumoses	1.88
Sugar	3.80	Ash	0.68
Casein	0.96		

Composition of Eagle Brand Condensed Milk (Holt):

	Undiluted. Per cent.	Diluted with six parts of water. Per cent.	Diluted with twelve parts of water. Per cent.
Fat	6.94	0.99	0.53
Proteids	8.43	1.20	0.65
Sugar	50.69	7.23	3.90
Salts	1.39	0.17	0.10
Water	31.30	90.49	94.82

Composition of Swiss, Austrian, and Norwegian Condensed Milk (Holt):

	With sugar. Per cent.	Without sugar. Per cent.
Water and volatile substances	20.0–30	46.5–55
Salts	1.5–3	2.0–3
Fats	8.0–12	13.0–20
Albuminoids	10.0–13	13.5–27
Lactose	10.0–15	12.5–18
Cane-sugar	30.0–45	....

Composition of WHEY from forty-six analyses by König:

	Per cent.
Fat	0.32
Proteids	0.86
Sugar	4.79
Salts	0.65
Water	93.38

Monti's estimate is:

		Per cent.
Fat		1.00
Proteids	Casein	0.03
	Soluble albumin	0.80–1.00
Sugar		4.50–5.00
Salts		0.70
Water		....

Composition of BEEF JUICE (Holt):

	Expressed by the warm process, one pound gives two and a half ounces. Per cent.	Made by the cold process, one pound, with eight ounces water, gives eight and a third ounces. Per cent.
Fat	0.60	....
Proteids	2.90	3.00
Extractives	3.40	1.90
Water	92.90	94.90
Salts	0.20	0.20

Composition of BEEF BROTH (Holt):

	Per cent.		Per cent.
Proteids	1.02	Salts	0.88
Extractives	1.82	Water	96.28

Composition of Barley-Water (Holt):

	Per cent.		Per cent.
Proteids..................	0.09	Starch......	1.63
Fat......................	0.05	Water..................	98.20
Salts....................	0.03		

Barley-Water is made as follows. Add two teaspoonfuls of washed pearl barley to a pint of water; boil slowly down to two-thirds of a pint and strain.

Oatmeal or Cracked Wheat Water (Starr).

Add one tablespoonful of well-cooked oatmeal or cracked wheat to a pint of water; allow it to simmer slowly for an hour or two, stirring constantly until a smooth mixture is obtained. Strain.

Rice-Water.

Soak one ounce of well-washed rice in a quart of water for two or three hours at a moderate heat; then boil for an hour and strain.

Barley Jelly (Starr).

Put two tablespoonfuls of barley flour into a quart saucepan with one and a half pints of water; boil slowly down to a pint. Strain and allow the liquid to set into a jelly.

Raw Beef Juice (Warm Process) (Starr).

Take one pound of sirloin beef, warm it on a broiler before a quick fire, and cut into small cubes. Express the juice with a meat press or a lemon squeezer. Remove the fat that rises on cooling. *Do not actually cook the meat.* Flavor with salt. Warm before giving, but do not heat sufficiently to coagulate the albumin.

Raw Beef Juice (Cold Process) (Holt).

Take one pound of finely chopped lean beef and eight ounces of water, allow to stand in a covered jar upon ice from six to twelve hours; then squeeze out the juice by twisting the meat in coarse muslin. Season with salt.

Beef Broth (Starr).

Mince one pound of lean beef, put it with its juice into an earthen vessel containing a pint of water at 85° F., and let it stand for one hour. Strain through stout muslin, squeezing all the juice from the meat. Place this liquid on the fire and, while stirring briskly, heat slowly just to the boiling point; then remove at once and season with salt.

Mutton Broth (Starr).

Add one pound of loin of mutton to three pints of water. Boil gently until very tender, adding a little salt; strain into a basin, and when cold skim off the fat. Warm when serving.

Chicken Broth (Starr).

A small chicken or half of a large fowl, thoroughly cleaned and with all the skin and fat removed, is to be chopped, bones and all, into small pieces. Put them with salt into a small saucepan and add a quart of boiling water; cover closely and simmer over a slow fire for two hours. After removing, allow it to stand, still covered, for an hour; then strain through a sieve.

Veal Broth (Starr).

Mince from one-half to one pound of lean veal and pour upon it a pint of cold water. Let it stand for three hours, then slowly heat to the boiling point. After boiling briskly for two minutes, strain through a fine sieve and season with salt.

Egg-Water.

Add the white of one egg and a pinch of salt to six ounces of cold water and mix thoroughly. This will be more palatable if sweetened.

Dextrinized Gruel (Chapin).

To one pint of gruel (made by boiling for fifteen minutes one tablespoonful of wheat, oatmeal, or barley flour with one and a half pints of water) add, when cool enough to be tasted, one teaspoonful of diastase or "Cereo" or of a thick malt extract. This mixture should be kept at a temperature of 150° F. for from fifteen to twenty minutes, until the gruel becomes thin and watery. The conversion of starch into dextrin and maltose will then be complete.

Peptonized Milk.

1. Rapid method. Take half a pint of milk, half a pint of water, two ounces of cream, and one measure of peptogenic milk-powder. Place on the range and bring to a boil in ten minutes. This should be cooled and kept in the refrigerator until used.

2. Use the same quantities as above and place the mixture on the back of the range or in water of a temperature of 115° F. for thirty minutes; then remove and put on ice or else bring the mixture quickly to the boiling point to destroy the activity of the digestive ferments.

3. If the same process as No. 2 is carried out for two hours the conversion of the casein into albumoses and peptones will be complete. (One measure or capful of peptogenic milk-powder must be added for each pint of the mixture prepared.)

Peptogenic milk-powder consists of sodium bicarbonate, pancreatin, and milk-sugar.

Liebig's Food (Leeds).

Take equal parts of wheat flour and barley malt, to which a certain amount of wheat bran is added (on account of the

phosphates and nitrogenous matter it contains). One per cent. of potassium bicarbonate is also added, and the whole is stirred with enough water to make a thin paste. It is then allowed to stand for several hours and heated to 150° F. until the conversion of the starch into maltose and dextrin is completed. The strained residue is then pressed and exhausted with warm water. The extract is evaporated and dried into a powdery mass.

Liebig's Soup (Monti).

Twenty cubic centimetres of wheat flour are mixed cold with two hundred cubic centimetres of unskimmed milk. The meal must be thoroughly mixed and heated over a slow fire (Mixture No. 1).

Twenty cubic centimetres of malted barley are mixed with forty cubic centimetres of a one per cent. solution of potassium carbonate. This is left standing for half an hour and then mixed with No. 1. After stirring for fifteen minutes it is heated to boiling and then strained. On account of the starch, it cannot be used before the fifth month. Children fed on it are subject to rickets, etc. It can, however, be added to the nourishment in the case of older infants when the supply of mother's milk is insufficient. It can also be used in weaning.

Scraped Meat.

Take a piece of raw juicy steak and scrape away the pulp of the meat with a dull knife or a piece of glass. Place this meat pulp (as much as is needed) on a piece of toast or stale bread and bake in the oven for five minutes. Flavor with salt and a small amount of butter. It can be administered either with or without the toast.

Oat Jelly (Rotch).

Two ounces of coarse oatmeal are soaked in a quart of cold water for twelve hours. The mixture is then boiled down so

as to make a pint and strained while hot. On cooling, a jelly is formed. Keep on ice until needed.

B. HENRY LEFFMANN. *Methods of Milk Analysis.*—For the determination of the proteids in milk two methods are in common use, termed respectively the Ritthausen and the Kjeldahl method. Each has been modified in details by different analysts. The Ritthausen method depends on the precipitation of the proteid matter by a copper salt and subsequent weighing of the curd so obtained, with due allowance for the fat and mineral matter that may be present. The Kjeldahl method depends on the conversion of the nitrogen into ammonium compounds and subsequent estimation of the ammonium. The amount of proteids is calculated by the use of the factor based upon the analysis of the different proteid matters. The Ritthausen method is subject to errors, most of which tend to increase the figures for the proteids. The Kjeldahl method is also subject to errors, some of which tend to diminish the figure for the proteids; but the principal errors in this method are that any non-proteid nitrogen (that is, the so-called extractives) is counted as proteid; secondly and more seriously, the factor for calculation is uncertain, as it differs with each form of proteid. American chemists usually employ 6.25 for cow's milk proteid; some prominent English chemists use 6.33. A factor as high as 6.67 has been recommended.

C. *A Clinical Method for the Estimation of Breast-Milk Proteids.*

GEORGE WOODWARD.[149] Ten cubic centimetres of the milk to be tested are placed in two glass burettes (five cubic centimetres in each) constructed with a glass pinchcock at the lower end to facilitate drawing off the serum. The burettes are then placed in a warm spot (from 95° to 100° F.) to favor fermentation. The time required to obtain distinct precipitation of the casein is from eighteen to twenty-four hours. When

the cream has fully separated as a solid yellow layer, the burettes are placed in cold water to increase the viscosity of the cream and from each the five cubic centimetres of serum are drawn into fifteen-cubic-centimetre graduated centrifugating tubes, leaving the cream *in situ*. The tubes are then filled to the fifteen-cubic-centimetre mark with Esbach solution (picric acid five grammes, citric acid ten grammes, water five hundred cubic centimetres).

The mixture is stirred with a glass rod and then revolved in a hand centrifuge until a constant reading is obtained. The estimates from the two tubes are taken and a mean derived from the sum of these. By a Kjeldahl control Woodward found this method to be fairly exact.

Leffmann-Beam Method for the Estimation of Fat.

D. The Leffmann-Beam method [257] for the estimation of the *fat* in milk or cream requires a specially constructed centrifugal machine and test-bottles with a capacity of thirty cubic centimetres, provided with a graduated neck, each division of which represents one-tenth per cent. by weight of butter fat.

"Fifteen cubic centimetres of the milk are measured into the bottle, three cubic centimetres of a mixture of equal parts of amyl alcohol and strong hydrochloric acid added, mixed, the bottle filled nearly to the neck with concentrated sulphuric acid, and the liquids mixed by holding the bottle by the neck and giving it a gyratory motion. The neck is now filled to about the zero point with a mixture of sulphuric acid and water prepared at the time. It is then placed in the centrifugal machine, which is so arranged that when at rest the bottles are in a vertical position. If only one test is to be made, the equilibrium of the machine is maintained by means of a test-bottle or bottles filled with a mixture of equal parts of sulphuric acid and water. After rotation from one to two minutes, the fat will collect in the neck of the bottle and the percentage may be read off. It is convenient to use a pair of

dividers in making the reading. The legs of these are placed at the upper and lower limits respectively of the fat, making allowance for the meniscus; one leg is then placed at the zero point and the reading made with the other. The results do not vary from those obtained by the Adams process by more than one-tenth per cent. and are generally even closer.

"Cream is to be diluted to exactly ten times its volume, the specific gravity taken, and the liquid treated as a milk. Since in the graduation of the test-bottles a specific gravity of 1030 is assumed, the reading must be increased in proportion.

"A more accurate result may be obtained by weighing in the test-bottle about two cubic centimetres of the cream and diluting to about fifteen cubic centimetres. The reading obtained is to be multiplied by 15.45 and divided by the weight in grammes of cream taken."

Modification of the Leffmann-Beam Method.[197]

A specially constructed graduated milk-bottle is required which will fit into any centrifuge used for urinalysis, etc. Five cubic centimetres of milk are introduced into the milk-bottle through a small pipette; one cubic centimetre of Reagent No. 1 is added, and the bottle well shaken. (Reagent No. 1: fusel oil thirty-seven parts by volume, wood alcohol thirteen parts, hydrochloric acid fifty parts.) Reagent No. 2 (sulphuric acid of a specific gravity of 1832) is added little by little with constant agitation until the bottle is filled to the base of the graduated neck. A mixture of equal parts of sulphuric acid and water is then added to reach a little above the highest (or first) graduation mark. The bottle is then whirled in the centrifuge for two minutes; the fat will then have risen in a clear yellowish layer which can be read in percentages from the scale on the neck of the bottle. If the milk be richer than five per cent. of fat, dilute equally with water. In testing cream, mix five parts of cream with twenty parts of water. The result should be multiplied by five.

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INDEX.

A

B

C

D

G

H

I

J

K

L

M

N

O

P

R

S

T

U

V

W

THE END.